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EDITORIAL.

ITEMS AND NOVELTIES.

The New Method of Electric Illumination.—Dr. Wilde, a member of the Academy of Sciences of St. Petersburg, and Director of the Central Physical Observatory, has recently made a report to the Academy upon the new mode of producing the electric light proposed by M. Ladyguin, of that city. Since the discovery of the voltaic arc in 1821 by Davy, many attempts have been made to utilize it practically for illumination. But in spite of the regulators devised for the purpose, it still remains variable and inconstant; being too intense used at a single point, it is yet incapable of division. Since the improved magneto-electric machines have reduced the cost of the electric light to only one-third that of coal gas, these efforts to utilize it have been redoubled. And, as a result, M. Ladyguin has made an invention which, in a very simple way, resolves both problems, rendering the light steady, and at the same time capable of division. It has long been known that the electric light proper comes from the intensely heated carbons which the current traverses, the resistance of the air between them developing this heat. So the resistance of a platinum wire placed in circuit causes it to be highly heated; but the light thus obtained, though constant, and entirely controllable, is too

feeble for practical use. M. Ladyguin has conceived the idea of replacing the platinum wire in this experiment by a thin rod of gas carbon; and with complete success. Carbon possesses, even at the same temperature, a much greater light-radiating power than platinum; its calorific capacity is less than one-half that of platinum; it is, moreover, a sufficiently good conductor of heat; so that the same quantity of heat elevates the temperature of a small rod of carbon to nearly double that of a wire of platinum the same size. Again, the resistance of the carbon employed is 250 times greater than that of platinum; hence it follows that a rod of carbon may be fifteen times as thick as a wire of platinum the same length, and yet be heated by the same current to the same degree. Finally, the carbon may be heated to the most intense whiteness without the danger of fusion to which platinum is liable. These are some of the advantages of carbon; its only disadvantage is, that heated in air it burns, and so gradually wastes. But M. Ladyguin has happily obviated this difficulty by enclosing the rod of carbon in a glass cylinder containing no oxygen and hermetically sealed. Dr. Wilde asks, in conclusion, that the Academy recognize the fact that M. Ladyguin has resolved the grand problem of dividing and rendering steady the electric light, in the simplest possible manner, and that they award him, in consequence, the Lomonossow prize.

On the Use of Copper Salts for Preserving Wood.—M. Rottier, an industrial engineer and an instructor in the University of Ghent, has recently communicated to the Belgian Academy of Sciences the results of numerous experiments which he has made upon the properties of wood prepared with salts of copper. We translate from the *Revue Industrielle* the following abstract of his paper. His purpose at the outset was to study the causes which result in the entire destruction of even prepared woods in a longer or shorter time, and to ascertain whether by the employment of methods different from those already in use it would not be possible to increase considerably the durability of wood. Very early in the investigation he established the fact that the comparatively short time for which copper sulphate preserves wood is due to the small quantity which enters into combination with the cellulose; this quantity being readily and completely removed in a short time. Shavings thoroughly impregnated with a solution of copper sulphate, then washed in pure water and dried, were buried in rich garden mould and kept moist by fre-

quent drenchings with rain water. In a short time, the quantity of copper sulphate in them was notably diminished, black spots appeared on the surface of the shavings, and they soon became rotten. The copper sulphate may be removed either by the presence of iron, of certain saline solutions, or of carbonic acid.

I. The first of these causes was established long ago. M. Rottier quotes an early experiment of his, made upon shavings prepared with solutions of copper sulphate containing different quantities of ferrous sulphate, which were subsequently buried and the time of preservation noted. The results of this experiment prove: 1st, that ferrous sulphate possesses a certain amount of antiseptic power, but much more feeble than that of copper sulphate. 2d, that woods prepared with solutions of copper sulphate containing at the same time ferrous sulphate, are preserved under ground nearly as long, unless the iron salt is present in considerable proportion. 3d, that there is no reason for preferring, for the purpose of preserving wood, a chemically pure copper sulphate to the commercial article. These last results are in contradiction to the theories of many specialists; among others, to those of M. Boucherie, who has lately stated that only pure or nearly pure copper sulphate could be used for the preservation of wood. M. Rottier quotes in support of his opinion the experiments made by Layen upon a very ancient wheel discovered in the copper mines of San Domingo, in Portugal. This wheel was found in a state of perfect preservation, although it had been immersed for fourteen centuries in water charged with copper and iron sulphates. The wood itself contained in notable quantities, basic sulphates of both the metals mentioned.

II. Again, a certain number of salts exercise a deleterious action upon wood impregnated with copper sulphate. If shavings prepared with copper sulphate are plunged, after being washed and dried, in a solution of calcium chloride, or of sodium or potassium carbonate, it will be noticed that after a short time copper appears in the solution, and that it steadily increases in amount while that in the wood becomes lessened. These facts prove that preservation with copper sulphate is not to be advised for woods which are to be employed in maritime construction; since these woods are attacked by borers as soon as a portion of the copper sulphate has been dissolved. In the same way may be explained the destruction of prepared woods employed in engineering, when they are buried in tunnels or in certain soils, espe-

cially in those which are calcareous; the water present being charged with calcareous salts (calcium bicarbonate, etc.) removes the copper from the prepared wood.

III. Precisely in the same manner, solutions of carbonic acid remove from wood the copper with which it has been prepared. To convince one's self of this fact, it is only necessary to treat prepared shavings with carbonic acid water.

In the second part of his investigation, M. Rottier experimented to ascertain whether an increase in the quantity of metal fixed upon the fiber would increase the durability of the wood. Special processes were necessary to test the question, since when wood is immersed in a solution of copper sulphate, the proportion of metal which combines with the fiber is nearly constant and always very small. He found: 1st, that the use of copper acetate enabled him to fix twice as much copper in the wood; 2d, that even this quantity was increased by heating the wood; 3d, that certain organic bodies act toward copper salts precisely as mordants do relative to coloring matters. These when introduced into the fiber become fixed there, and then cause there the absorption of much more considerable quantities of copper. Experiments are described which were made with the two organic substances which have given the most noticeable results, indigo and catechu; and 4th, that the employment of cuprammonium salts enables a very large quantity of copper to be introduced into the wood. In all the experiments, shavings being prepared according to the different processes and their durability noted, it appeared that this durability was in the direct ratio of the amount of copper fixed by the fiber. The following are the author's conclusions: Among all the various methods of preparing wood which I have now considered, there is only one which appears to me susceptible of practical industrial application with advantage. The high price of copper acetate and of indigo necessitates the rejection, undoubtedly, of these substances for this purpose. The heating of wood injected with copper sulphate does not give results of paramount value, and the employment of catechu is possible only in certain cases of not frequent occurrence. The cuprammonium salts on the contrary may be employed in the great majority of cases, and the small increase in the expense resulting from their use in the preservation of wood will be largely compensated by the much greater durability thus given to the fiber.

The Gramme Magneto-Electric Machine.—We find in the London *Engineer*, of April 2d, the following note from Mr. Wilde, the well-known inventor of the magneto-electric machine bearing his name. As a contribution to the history of the Gramme principle of "endless bobbins," the fact stated by Professor Pacinotti is of great importance.

SIR: I wish to direct attention, through *The Engineer*, to a project which has of late been brought prominently into notice. It is now about two years since Gramme's patent magneto-electric machine was brought, by some speculators, from Paris into this country. The novelty of this machine consisted in giving to the armature the form of a closed ring, wrapped round with a series of small coils of insulated wire, in such a manner that when the ring was caused to rotate before the poles of a permanent or an electro-magnet, a continuous and approximately uniform current of electricity was obtained. This form of armature, I would observe, possesses no practical advantage over the well-known forms contrived by Saxton and Siemens, when arranged to produce the direct current from a well-constructed commutator, but it has the disadvantage of requiring a commutator of complicated construction, and of not producing the alternating current now employed for lighthouse illumination. Had M. Gramme limited the exercise of his ingenuity to improving the magneto-electric machine of which he claims to be the inventor, it might have found a respectable place in the laboratory of the physicist as an instrument of research; but he and those associated with him have, for the purpose of bringing the invention into notice, adopted the principle of electro-dynamic accumulation to produce electric light from an electro-magnet, which, as is well known to those familiar with the history of electrical science, forms no part of Gramme's invention. With the view of giving further publicity to the Gramme machine, the promoters of the speculation obtained permission of the Board of Works to exhibit at their own expense, an electric light from the clock-tower of the Houses of Parliament at Westminster, and with this semblance of Governmental patronage, aided by articles in the *Quarterly Journal of Science*, and other publications, "The Electric Power Company (Limited)" was formed to purchase and work the Gramme invention. The nominal capital of this company was £100,000, out of which the promoters were to receive £65,000. As a small amount only of capital of this company was subscribed by the

public—an amount which would appear to have been insufficient to repay the promoters for their venture—a new company has been recently formed, called "Gramme's Magneto-Electric Company (Limited)" with a nominal capital of £250,000. Out of this capital the vendors of the Gramme invention are to receive the modest sum of £145,000, and, to show their confidence in the undertaking, they have considerately agreed to accept £35,000 of this amount in paid-up shares of the company.

I now come to the more important object of my communication. A short time since, Dr. Antonio Pacinotti, of the University of Pisa, was good enough to send me a reprint of his memoir "Sulle Elettro Calamite Trasversali," from the *Nuovo Cimento* of 1864, vol. xix, p. 378, which contains a description of an electro-magnetic machine with an armature in the form of a closed ring, wrapped round with a series of small coils of insulated wire, in the same manner precisely as in the machine of Gramme. The learned Italian Professor states in his memoir that he had one of these machines constructed as early as 1860, for the Cabinet of Technological Physics of the University of Pisa, and that, with either permanent or electro-magnets, it could be used as a magneto-electric machine for producing a continuous current: "Una macchina magneto-elettrica con currente continua," p. 383. The volumes of the *Nuovo Cimento* are to be found in the libraries of the Royal Institution, London, and other learned societies in Europe and America. The memoir is illustrated with an excellent engraving, from which it will be seen that Signor Pacinotti has anticipated most completely the communication of M. Gramme, entitled "Sur une machine magneto-electrique produisant des courants continus," published in the *Comptes Rendus de l'Academie des Sciences*, tome 73, page 175, 1871, as well as his English patent of 1870, No. 1668. What renders the Gramme scheme the more remarkable at the present time is the fact that, in the month after the appearance of Gramme's note in the *Comptes Rendus*, Signor Pacinotti sent his reclamation of the invention to the French Academy, where it was admitted, as will be seen by reference to p. 544, and to the index of tome 73, where it is described as "Une machine electro-magnetique construite en 1860 d'après le même principe que la machine de M. Gramme." It is scarcely necessary for me to state that, as Signor Pacinotti's memoir of 1864 is to be found in the public libraries of this and other countries, the knowledge therein communicated belongs

to the commonwealth of learning, and cannot be made the subject of a valid patent. The publication of these facts, to which I have felt it my duty to draw attention, will, doubtless, prove of public advantage.

H. WILDE.

Alderley Edge, near Manchester, March 23.

The Centennial Exhibition.—As was anticipated at the date of the last issue of the JOURNAL, the opening of Spring was the signal for greatly increased activity in the building operations at the Centennial grounds.

The contractors are evidently alive to the importance of pushing forward the work as rapidly as possible, and although somewhat retarded by the unusually late spring, have made very satisfactory progress.

Railroad tracks have been laid into the site of Machinery Hall, and an immense amount of material has been delivered. A planing mill has been erected on the spot, and a considerable portion of the frame-work of the north aisle has been erected. Several hundred men are employed on the various portions of this work.

The work on the Art Building has also advanced greatly. On nearly the entire south front, the granite is set to the height of the top of the columns of the portico, say fifty feet; and is progressing with equal rapidity on other portions. The brick-work on the interior walls is stretching up rapidly, and the setting of the iron-work of the base of the dome will be begun in a few days. Two of the four colossal figures for the base of the dome are modeled and are now being cast in a foundry erected on the spot for that purpose.

Work on the Main Exhibition Building is making good progress.

The engineers and architects, Messrs. Pettit and Wilson, have arranged for a comprehensive system of water supply and drainage which is now being executed.

The arrangement of the principal buildings, a plan of which accompanies this, has been slightly modified from the original design and will be found admirably adapted to the wants of the exhibition.

The grounds comprise 230 acres, lying a short distance west of the Schuylkill river, and are of nearly triangular shape, bounded on the south by Elm Avenue from 41st to 52d street; on the west by the drive to George's Hill; on the north by Belmont drive; the eastern boundary cuts off Landsdown drive which will be turned north and

bridges thrown across Landsdown and Belmont valleys, which with a short stretch of new road between them, will complete the circuit of the enclosure.

There will be thirteen entrances representing the original number of states, and after which they may be named, and at each of these will be ticket offices and turn stiles to record the number of visitors.

Belmont Avenue will be closed at its intersection with Elm Avenue and here the administration offices will be located.

The Main Exhibition Building and Machinery Hall stretch along Elm Avenue, one on either side of Belmont Avenue, with a space of 500 feet between them, which will be laid out in walks and handsomely ornamented.

Horticultural Hall is situated on a plateau of about 16 acres, with the deep ravines on the north and south, known respectively as Belmont and Landsdown valleys, and immediately north of this lie the agricultural grounds of 30 acres with its building.

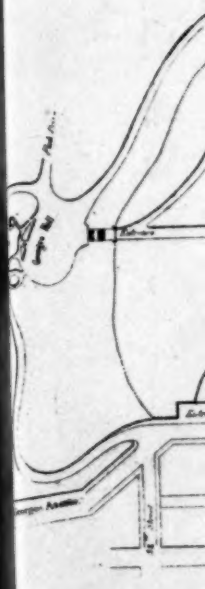
The United States government exhibition building will be near Belmont Avenue, about 800 feet north of Machinery Hall.

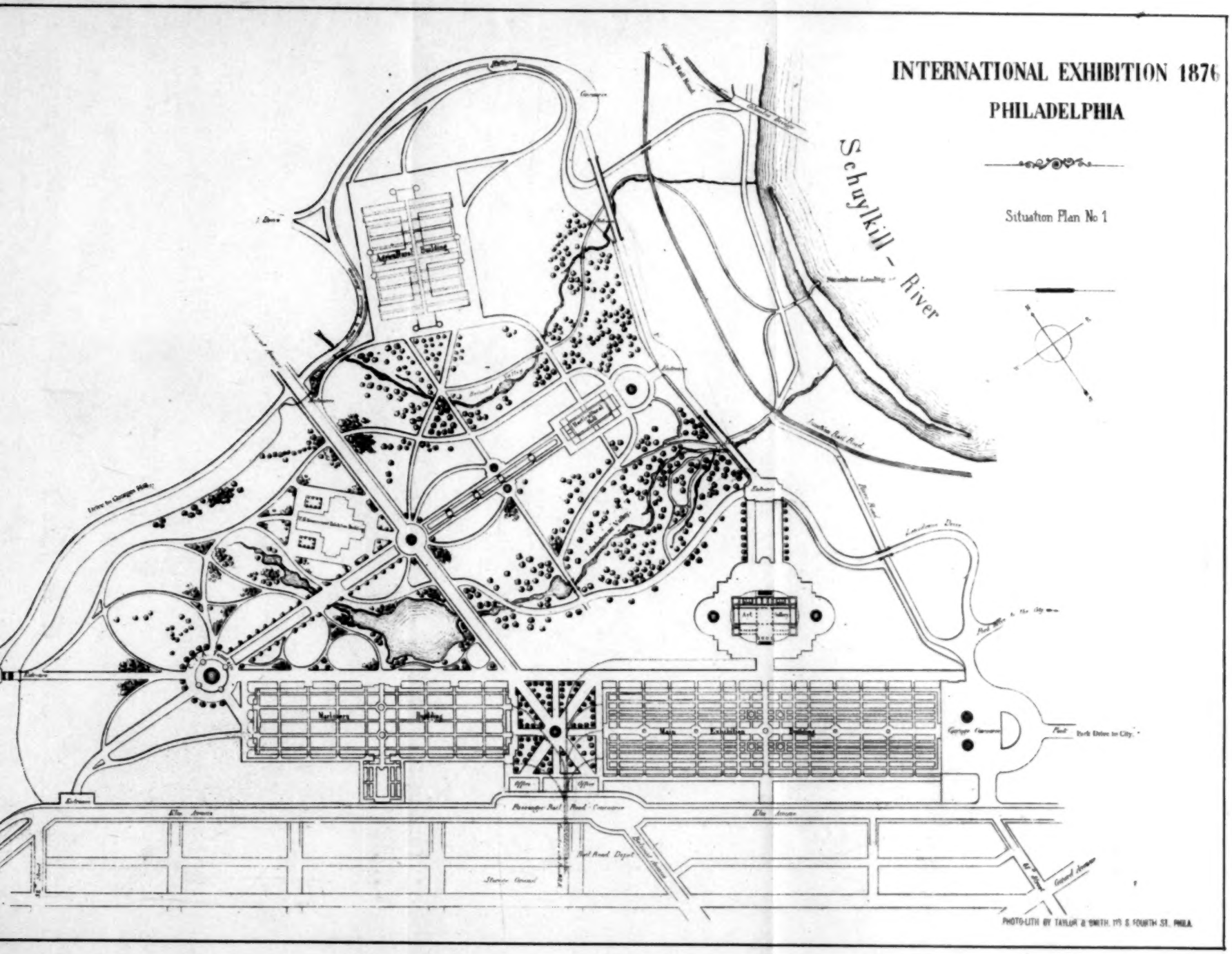
This arrangement gives ample space between the principal buildings to locate satisfactorily smaller ones for the use of foreign government commissions and those for special exhibits of which there will no doubt be a large number.

Among the proposed ornamental improvements to the Grounds, are the Terraces around the Art Building and its grand approach from Lansdown drive on the north. The fountain of the Catholic Total Abstinence Society to be placed at the foot of George's Hill, a little northwest of Machinery Hall; the lake in front of the same building; the Terraces and Grand Flower Parterre in the Horticultural Grounds.

The dimensions of the principal buildings are as follows:

Main Exhibition Building,	1880 ft.	× 464 ft.	= 20	acres.
Machinery Hall,	1402 "	× 360 "	= 12	"
Art Building,	365 "	× 210 "	= 1½	"
Horticultural Hall,	350 "	× 160 "	= 1¼	"
Agricultural Hall,	820 "	× 540 "	= 10	"
U.S. Government Exhibition Building,	360 "	× 130 "	= 1½	"
Administration Offices,	320 "	× 80 "	= ¾	"
Making a Total of			47	"




INTERNATIONAL EXHIBITION 1876
PHILADELPHIA
Situation Plan No 1
Schuylkill River
Main Exhibition Building
Machinery Building
Art Gallery
Agricultural Building
Horticultural Building
Memorial Hall
Ellis Avenue
Passenger Rail Road Crossing
Rail Road Depot
Belmont Avenue
Lansdown Drive
Fountain Rail Road
Entrance to Georges Hill
Georges Cemetery
Park Below the City
Statue Avenue
PHOTO-LITH BY TAYLOR & SMITH, 119 S. FOURTH ST. PHILA.

The length of the proposed Horse Railroad within the enclosure for transporting passengers is about 4 miles, and the Freight Railroad tracks for the delivery of goods about 3½ miles, connecting through the Penna., Reading and Junction Railroads with the entire railroad system of the country.

The bridging of the Penna. R. R. at 40th and 41st streets has been so far arranged for that its accomplishment may be considered certain, thus greatly facilitating the approach to the grounds in carriages, especially from the southern and western portions of the city.

K.

The Mills Portable Engine.—The severe test to which the capacity of the Steam Boilers and Portable Steam Engines was subjected at the late Exhibition of the Institute, will make the following statement of the trial of the Portable Engine, known as the "Mills," of interest to engineers and users of this class of machines.

DEAR SIR—The results of the test of the "Mills Engine," made by me on the 4th and 5th inst., in the City of New York, is as follows. The engine is what is claimed, of six-horse power, net, of the following general dimensions, arranged on a boiler of the locomotive type :—

Diameter of the cylinder,	6·	inches
Stroke of the piston,	6·	"
Balance-wheel, or pulley,	6x36·	"
Revolutions for the power named,	200·	
Diameter of boiler—largest part,	19·5	inches
" " smallest part, inside,	18·	"
Number of tubes,	42·	
Length "	6·	feet
Total water-heating surface, taking outside of tubes,	90·	sq. ft.
Total area of fire-grate, all used,	2·15	"
Diameter of blast-pipe,	1·25	inches
" " smoke-pipe above engine,	7·	"
Length " " " "	8·	feet

Governor of usual description (Waters' patent).

Single slide Davis' patent piston valve, worked by a fixed eccentric.

Boiler jacketed with one-inch felt, and covered with Russia iron.

Weight of engine, boiler, road wheels, etc., a trifle under 3500 lbs.

RESULTS OF THE TEST.

Average steam-pressure carried,	86·3	lbs.
" temperature of feed-water in tank,	42·	degs.
" " " " entering boiler,	210·1	"
" " " smoke (5 in. from tube ends),	421·2	"
" " " steam due to pressure,	321·1	"
Coal weighed out and used,	200·	lbs.
Wood and shavings used,	12·	"
Ash and clinker at end of trial,	53·	"
Water used from tank,	1,312·	"
Total revolutions with full load,	56,268·	
Hours run at actual speed—*mechanical time*,	4·689	
" " " clock time,	4·75	
Indicated horse-power,	7·63	
Water, per indicated horse-power, per hour,	36·2	lbs.
Combustible, per indicated horse-power, per hour,	4·05	"

REMARKS.—To obtain correct evaporative duty of boiler, the water derived from condensation in the heater must be calculated and added to amount drawn from the tank, as the feed-water was heated in a direct contact heater. Owing to the coal being larger than had previously been used, considerably more was put in fire-box during first hour than necessary, causing a loss that could not be calculated, and was not considered. Temperature of feed-water is the average taken by another and myself at different intervals—or one-quarter hour apart.

F. W. BACON,
Mechanical and Consulting Engineer.

Boston, March 10, 1874.

The Rules under which this test was made accompany the Report, over Mr. Bacon's signature, but as they are almost identical with those governing the tests at the Exhibition, and which were published in the JOURNAL for August, 1874, their repetition here is unnecessary. K.

A New Seismometer.—A highly ingenious, though simple, apparatus, designed by M. Malvosia, of Bologna, to indicate the commencement of earthquake shocks, has lately attracted the attention of Italian *savants*. We will try, briefly, to describe it: On a

slightly inclined board is fixed a spherical cap or *calotte* having eight grooves corresponding to the eight principal points of the compass. A little beyond the edge of the cap there is a projecting wooden ring which limits the inclined surface. On the top of the cap is poised a little brass ball, being slightly flattened at the point of contact. Upon the ball rests very lightly a conical weight by a small screw projecting from its base; which weight is suspended by a chain from an overhanging arm movable up and down on a support at the side. It will thus be seen that the least shock will make the ball topple over. When it does so, it runs down one of the grooves of the cap to the inclined plane, at the lower part of which it finds a hole, and passing into it, comes to effect an arrangement by which a gun is fired. But this is not all. Whenever the ball has left its position on the cap, a spring needle, longer than the diameter of the ball, shoots out from the little screw-knob that rested on the ball and catches in that groove of the cap down which the ball has run. Thus the direction is indicated in which the shock has been given; it has been on the opposite side to that in which the needle hangs down. The instrument is said to be very sensitive, and will doubtless render good service in what is now a little understood branch of science.

New Fog Signals.—Professor Tyndall has recently made a series of experiments at Woolwich, England, upon a new signal apparatus for use on the coast during fogs. It consists of a cannon by means of which detonations of variable intensity may be produced. This is effected by the concurrent employment of gunpowder and of gun-cotton.

Bibliographical Notices.

TECHNICAL TRAINING; *being a Suggestive Sketch of a National System of Industrial Instruction, founded on a General Diffusion of Practical Science among the People.* By THOMAS TWINING, one of the Vice-Presidents of the Society of Arts. 8vo., pp. xxiv, 458. London, 1874. (Macmillan & Co.) The subject of Technical Training is one in which just now England is deeply interested. Deaf as she was for a long time to the warnings of some of the most far-

sighted of her scientific men, the Exposition of 1867 opened her eyes to the fact that an era of brains was taking the place of one of simply manipulative skill, and that intelligent, well-trained intellect was a better crop to cultivate than manual dexterity or empirical prestidigitation. Hence have arisen here and there over her domain schools of various grades designed for the mental training of her artisans; so that out of the developed brain should come new ideas of progress which would enable her to maintain her prestige among the nations. But more than this. The subject of education generally, and especially that of the higher education, has received a most valuable impulse from this movement. Broader and more liberal ideas are taking possession of British educators. The masses are to be put to school; they are to be trained in mind as well as in body; to be taught how to grasp and wield an idea as readily as a sledge. Out of this general advance along the line, the book before us comes. Its author has for many years been studying English and Continental Technical Education, and has carefully examined all the plans which have originated, with working men or outside of them, for the improvement of their mental condition. On the very many perplexing questions which arise when the subject of Technical Training is discussed, therefore, he is a most invaluable witness. For example, he cuts at the outset a Gordian knot of no mean proportions when he says: "Train each portion of the community to the full enjoyment of its resources, and to the satisfactory fulfillment of its duties." He believes that there is no danger of too much education anywhere; that the needs of the laboring classes will always impel them rather to too little than to too much study. Hence he would reorganize the apprenticeship system, would provide evening and science and art schools for the working man, and would furnish him with museums where he can see for himself the progress made in branches of labor other than his own. But over and above all this is the grander and wider plan of engrafting technical upon the entire system of national education, so that from his childhood the artisan shall be instructed in those branches of knowledge which he is afterwards to put into practice. In furtherance of this idea, Mr. Twining gives in his book definite plans for systematic instruction, both elementary and advanced; the text books and books of reference necessary in the various parts of the course, the methods of instruction likely to be of most benefit, and finally the examinations which are held at the close. For special purposes, he thinks a central technical university may become necessary, and submits a plan of such a school. Without entering here upon the question how far our system of general education resembles that of England, it is quite clear that in technical education we are in quite as much need of bestirring ourselves as are our English cousins. We too must have schools for training mechanics in science; not only institutions where our young men can afford to spend years in studying a learned profession, be it that of

civil engineer or analytical chemist, but schools where scientific principles, even the most elementary, if need be, can be taught to those who are earning their daily bread by the sweat of their brows during the very time they come for instruction. We commend Mr. Twining's book to all who are interested in this great subject. Especially to those who, having both benevolence of heart and fullness of pocket, are desirous of ameliorating the condition of the working man, as the proximate object, and of placing us in the higher industries, at least by the side of the mother country, as the ultimate object of their benefactions.

MANUAL OF DETERMINATIVE MINERALOGY, *with an introduction on Blowpipe Analysis.* By GEORGE J. BRUSH, Professor of Mineralogy in the Sheffield Scientific School. 8vo, pp, vi. 104. New York, 1875. (John Wiley & Son.)—Professor Brush's eminence as a mineralogist, and his ability and experience as a successful teacher of mineralogy, are well known facts. For this reason we are glad to welcome from his pen the volume before us, which is intended to be one part of the Determinative portion of Dana's Mineralogy. The material in it, he tells us in his preface, was in great part prepared several years ago, and has since been used in his own instruction. It consists of a preliminary portion upon Qualitative Blowpipe Analysis—upon which subject Professor Brush stands as the acknowledged authority in this country—and of a subsequent portion, embracing Determinative Mineralogy proper. This latter portion is based upon the tenth edition of Von Kobell's well-known "Tafeln zur Bestimmung der Mineralien," although much new matter has been added, and the old has been much more conveniently arranged in a set of thirty-three tables, preceded by a complete analysis, by which with the aid of the blowpipe, the mineral under examination may in a few moments, be referred to its proper place. The determinative characteristics as given in the tables are color, streak, cleavage, hardness, specific gravity, fusibility, crystalline form, chemical composition and behavior. From this statement it will be seen that the means which are employed for the determination of mineral species are chiefly pyrognostic, and that after the mineral has been thus fixed, the other physical characters are given to complete the identity. The author expresses his intention to add at some future time other tables for the determination of minerals by their physical characters alone. This will add greatly to the usefulness of the work. We trust also that the crystallographic portion will soon be put into print, since a good English treatise on the system of crystallography adopted by Dana is yet a desideratum. Professor Brush's book is well and carefully printed, and is creditable to the house which has issued it.

Franklin Institute.

HALL OF THE FRANKLIN INSTITUTE, March 17th, 1875.

The stated meeting was called to order at 8 o'clock P. M., the President, Robt. E. Rogers in the chair. There were 129 members present.

The minutes of the stated meeting held February 17th last were read, and after some discussion were adopted as read.

The Actuary presented the minutes of the Board of Managers, and reported that at their stated meeting held the 10th inst., the following donations to the library had been received:

Annual Report of the Secretary of the American Iron and Steel Association, Dec. 31st, 1874. Philada. From the Association.

Statistical Society Almanac for 1875. London. From the Society.

Narrow Gauge Railways in America, also a Directory of Narrow Gauge Railways in North America, by Howard Fleming. From the Authors.

Fifth Annual Report of the Directors of City Trusts, Report for the year 1874. From the Board of City Trust.

The Secretary reported from the Committee on Models that they had met and organized, and had asked the Board of Managers for an appropriation of one hundred dollars, to be expended in putting the Cabinet of Models in order. This appropriation has been made, and is now being expended under the direction of the committee.

The Secretary presented his report, which was principally devoted to lantern illustrations of the Centennial Exhibition grounds and buildings, with descriptions; and some comments on the success of the late exhibition held by the Institute.

He also presented a new castor for furniture, the invention of G. W. Waite, the principal peculiarity of which consists in the weight being sustained by a series of conical rollers standing on end at a small inclination from the perpendicular, between a central spindle and an outer case, enabling the castor to adjust itself to any desired line of motion with a very small amount of friction.

The Secretary also stated that considerable interest had been felt in the matter of magneto-electric machines, from the fact of a Gramme machine having been recently put in operation by Prof. Barker, at the University of Pennsylvania, and hoped that it would be exhibited at the next meeting.

In response to the request of the President, Mr. C. L. Chapin gave some account of the efforts being made to introduce these machines in this country, and stated that he hoped they would soon be put on this market.

Under the head of deferred business the proposed amendments to the by-laws laid over from the last meeting were called up, which are as follows:

Resolved, That Section III, Article 5, of the by-laws, be amended by changing the hours of opening the polls from 4 o'clock to 3 o'clock P. M., and the hour of closing the polls from 8 o'clock to 9 o'clock P. M.

Resolved, That Section I, of Article 5, of the by-laws, be amended by adding to the first sentence the following: "And provided further, that no member shall be eligible for re-election as Manager or Vice-President, for the period of one year after his term of office has expired."

A very wide discussion followed, participated in by Messrs. LeVan, Close, Helm, Hoover, Brown, Purves, Sartain, Trautwine, Eldridge, Tatham, Mitchell, Lipman, Weaver and Heyl. On being put to vote separately, the resolutions were lost.

In reply to a question the Secretary stated that the number of season tickets to the Exhibition issued to members was 1324, to exhibitors 803, to the employees of exhibitors 1167, making a total of 3284 free season tickets, exclusive of press and other complimentary tickets.

Mr. Close asked the chair to make a decision as to the exact construction to be put on the by-law requiring the polls to close at 8 o'clock, and as to whether or not those members who are in line at that hour shall be allowed to deposit their ballots.

Mr. Grimshaw stated that he had embodied that point in a proposed amendment to the by-laws, which he handed the Secretary, as follows: "Amendment offered to Section III, Article 5, to change the hour of opening the polls, from 4 o'clock to 3 o'clock, and to insert the words, all voters who shall be present in the room of election prior to 8 o'clock P. M. shall be entitled to have their votes received."

The President said, I think in fairness to those who come, under circumstances, sometimes, of unavoidable delay, that it would be even-handed justice that all who are in the voting room at the time, and all in line are at liberty and should have the privilege of voting. This is my decision.

Some discussion followed, but no appeal was taken from the decision, whereupon Mr. Grimshaw withdrew his proposed amendment.

Under the head of new business the following extract from the minutes of the Board of Managers was presented:

"The Secretary presented a memorandum showing the attendance in the Library on Sunday, from August 1st, 1874, to February 7th, 1875, between the hours of 12 M. and 4 P. M, was an average of 3¼ persons per day, and from 10 A. M. to 4 P. M. there was an average of 5 per day, and many of these were persons who could as well use the library on other days, or in the evenings. The Secretary therefore offered the following, which was adopted:

"*Resolved*, That in view of the small attendance at the library on Sunday, as shown by the memorandum, the Board of Managers recommend to the Institute that its opening on Sunday be discontinued."

Mr. Purves moved, and it was seconded, that in accordance with the recommendation of the Board of Managers, the opening of the library on Sundays be discontinued.

Mr. Chabot moved to amend by postponing action for three months, and in the mean time a record be kept of the attendance during the week and on Sunday; which, on being put to vote, was lost.

The question recurring on Mr. Purves' motion, it was carried.

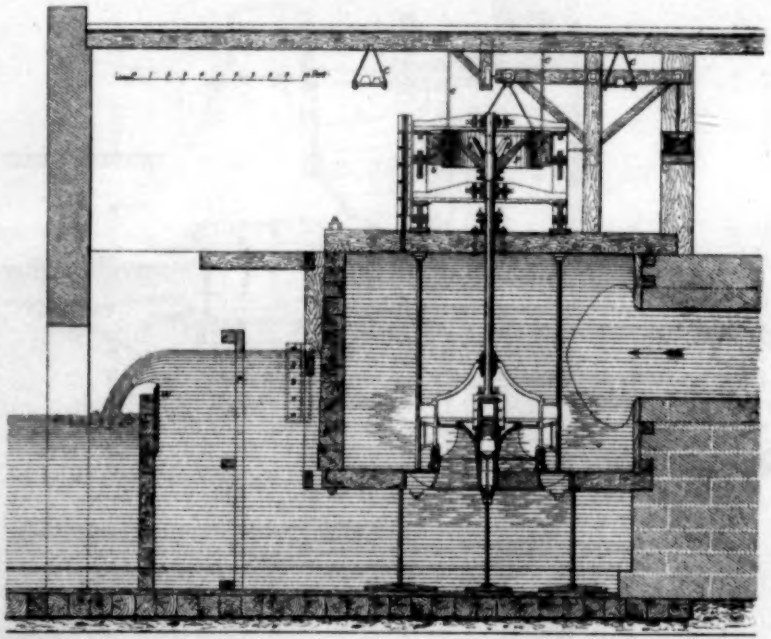
Mr. Chabot wished to have his vote recorded "*No.*"

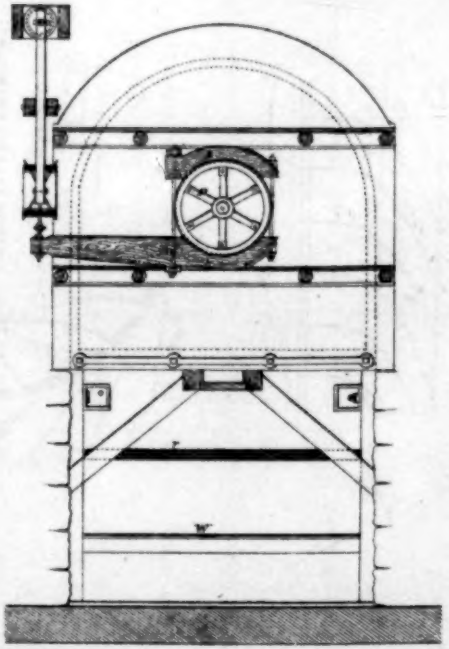
The President urged upon the members the importance of each doing all they can in bringing matters of interest before the monthly meetings, and assured them that they will always meet with the hearty co-operation of the Secretary and other officers of the Institute.

The meteorological section filed a report on the climatic conditions during the months of January and February of this year.

On motion the meeting then adjourned.

J. B. KNIGHT, *Secretary.*





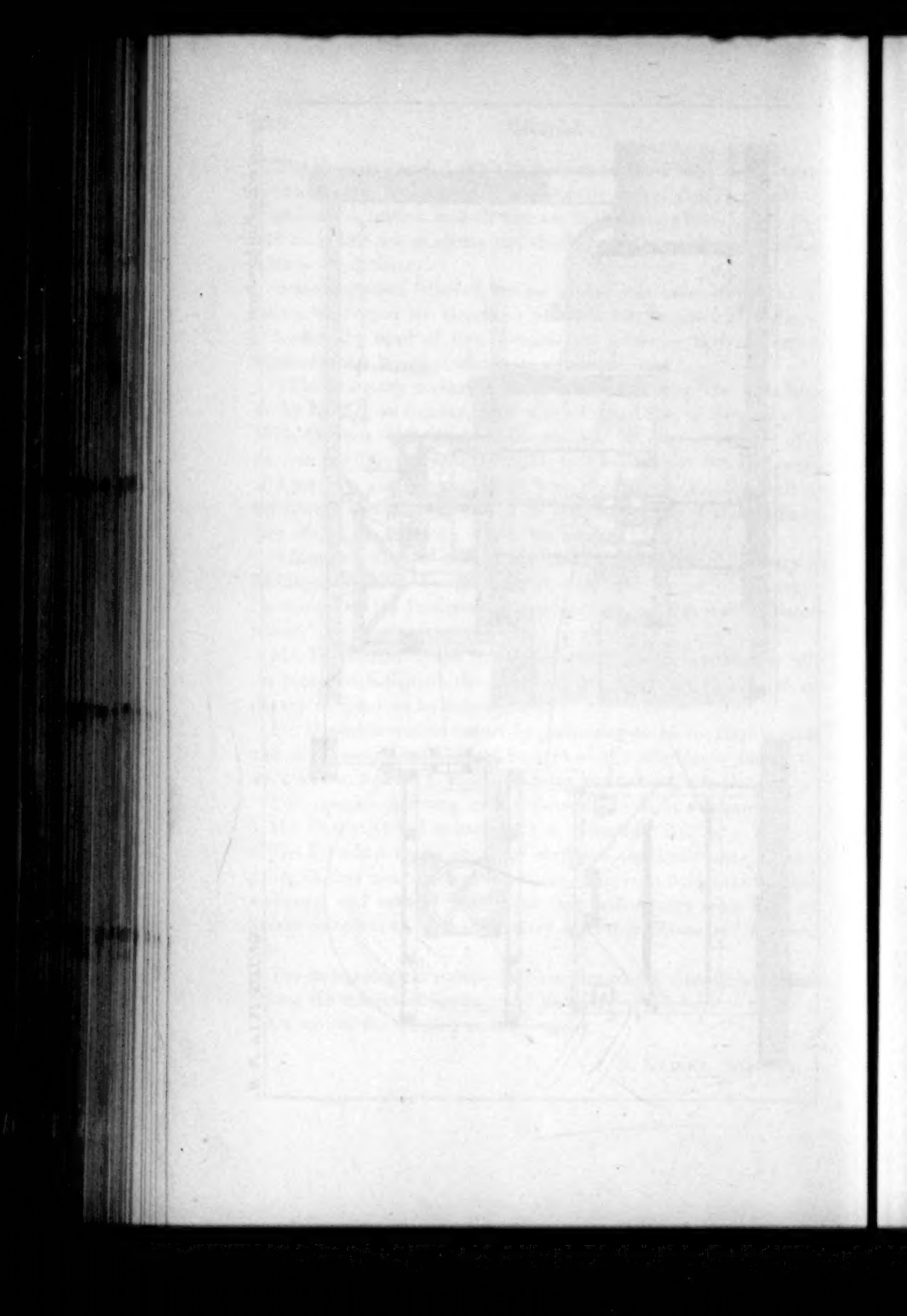


Fig. 1.

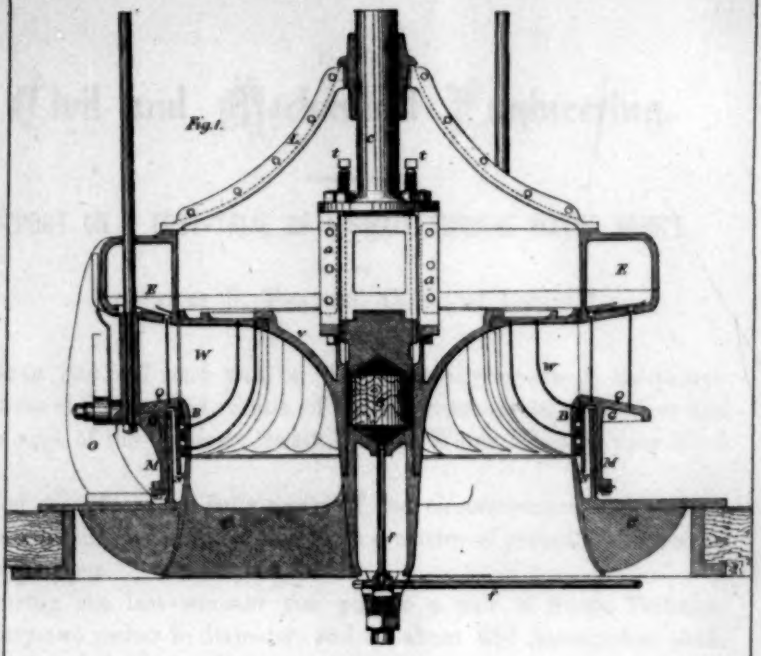
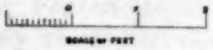


Fig. 2.

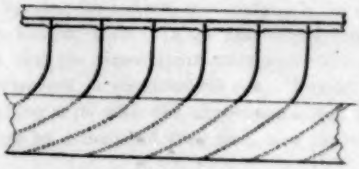
SWAIN TURBINE COMPANY'S

72 INCH WHEEL

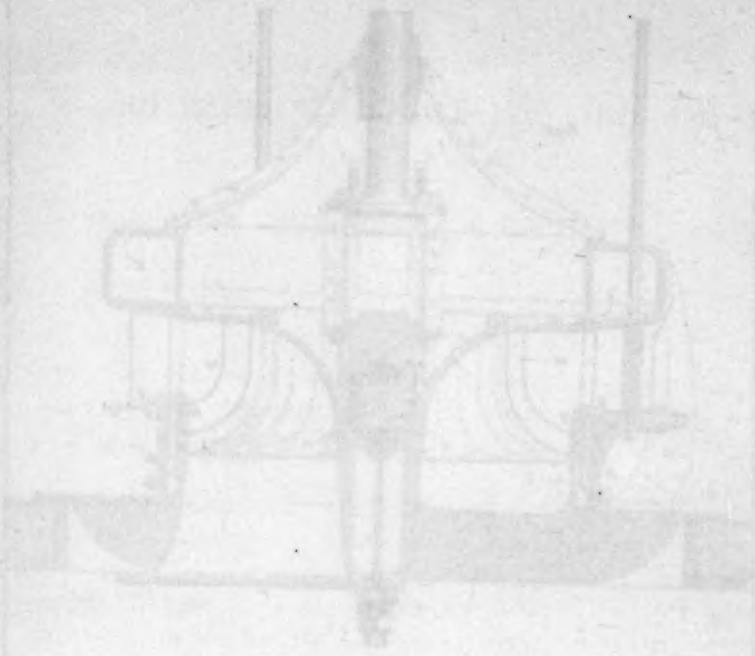


SCALE OF FEET

Fig. 3



Lith. Lemoine & Co. Phila.



Civil and Mechanical Engineering.

REPORT ON A TEST-TRIAL OF A SWAIN TURBINE WATER WHEEL.

By James B. Francis, C. E., of Lowell.*

Dear Sir:—I send you, on the accompanying sheets, the principal data and computed results of the experiments on the Power and Discharge of the Westerly Swain Turbine Water Wheel in your No. 5 Mill.

You are, of course, fully aware of the circumstances under which these experiments were made, but as a matter of record I will briefly describe them.

During the last summer you put in a pair of Swain Turbines, seventy-two inches in diameter, and of about 330 horse-power each, on 18 feet fall; both of the same pattern; in place of the Centre-vent Wheels that had been in use in the same mill since it was built, in 1849; and it became necessary, for the purpose of gauging the quantity of water drawn by the Boott Cotton Mills from the canals of the Proprietors of the Locks and Canals on Merrimack River, to ascertain the quantity of water discharged by them at different heights of speed-gate, and with different speeds. For this purpose a gauging weir was constructed below the Westerly wheel, over which all the water flowed which passed through the wheel. This was all that was required for the purpose of gauging the quantity of water discharged. At your request, however, I at the same time weighed the power of the wheel, for the purpose of ascertaining its efficiency as a motor.

[* The Report on the Swain Turbine here given, was made to A. G. Cumnock, Esq., Agent of the Boott Cotton Mills, Lowell, Mass. In the note accompanying the manuscript sent us, the author states that the experiments were made with great care, the necessary apparatus being constructed at considerable cost. He also states that the makers of the Turbine had nothing to do with the experiments, and bore no part of the expense; they must therefore be considered free from any bias in favor of the makers.—Ed.]

The apparatus used for weighing the power was substantially the same as was used in testing the Centre-vent Water Wheel in the same mill, in 1849, a description of which is given in "Lowell Hydraulic Experiments," the second edition of which was published in 1868. The friction pulley and the bell crank were identically the same as used before. The brake was new. The hydraulic regulator was the same as was used in testing the Tremont Turbine in 1851, and is also described in the work above referred to.

The principal difference in the apparatus was in the weir, which in this case was without contraction at the ends. This was so made in order to obtain a greater length of weir; the power, and, of course, the quantity of water discharged, being considerably greater in the Swain wheel than in the Centre-vent wheel it replaces. The formula determined from the experiments made at the Lower Locks, in 1852, for computing the flow over a weir requires complete contraction at the crest, and either complete contraction, or none, at the ends. In this case the contraction at the crest was complete, and at the ends nothing; the discharge has been computed by the formula

$$Q = 3{\cdot}33\ LH^{\frac{3}{2}}$$

In which

Q = the quantity of water discharged, in cubic feet per second.
L = the length of the weir = 16·311 feet.
H = the depth on the weir, in feet.

The discharge from the wheel caused great commotion in the wheel-pit, and the weir being too near to permit the water to free itself, naturally, from disturbance before reaching the weir, a rack or grating in which about one-fifth of the area was open for the passage of the water, was placed parallel to, and about 4·5 feet distant from the weir; the relative position of wheel, rack and weir, being the same as in the experiments on the Centre-vent wheel in 1849, and represented on Plate VIII "Lowell Hydraulic Experiments." The fall in passing the rack (on which its efficiency in equalizing the flow mainly depends), in the experiments with the speed-gate fully open, was about 0·2 feet. The crest of the weir was 12·08 feet above the bottom of the race-way. The depth on the weir was observed by means of a hook-gauge, placed in a tight box on the upper side of the rack, which communicated by means of a lead pipe 0·75 inch in diameter with the space between the rack and the weir; the lower part of the

pipe being placed an inch or two above the floor of the wheel-pit, in the angle formed by the floor and the weir, where there is the least motion in the water; the lower end being closed, and the communication maintained by means of holes in said lower part of the pipe, one-eighth inch diameter, one foot apart. The water had a free fall from the weir, the height of the water on the down-stream side of the weir, being in no experiment less than 2·5 feet below the top of the weir. The fall acting on the wheel was observed by noting the height of the water in the wheel-pit and the head in the penstock, substantially as in the experiments of 1849, above referred to. The box containing the gauge for observing the height in the wheel-pit, communicated with the wheel-pit, by means of a lead pipe 0·75 inch in diameter, placed in the angle formed by the floor and wall of the pit, pierced with holes one-eighth inch diameter, about one foot apart. The brake was of oak, the long arm having an effective length of 10·760 feet, which was increased by the unequal lengths of the arms of the bell-crank to $10{\cdot}760 \times \frac{5{\cdot}000}{4{\cdot}495} = 11{\cdot}969$ feet.

The weight of the brake was . . .	3228·75	pounds.
" " friction pulley, . .	5025·00	"
	8253·75	"

The friction pulley takes the place of a bevel gear weighing 2440 pounds. The difference between the weight of the brake and friction pulley and the bevel gear, viz., 5813·75 pounds, was counterbalanced by a combination of suspension rods, levers and weights, which left the same weight on the step on which the wheel runs, during the experiments, as in the ordinary running of the wheel. The counterbalance relieves the step of the extra weight, by means of the brake lifting against the upper flange of the friction pulley.

The weights used were mostly pieces of pig iron of various weights, which were marked upon them by the City Sealer of Weights and Measures. As a check, the weights in the scale were frequently taken out and weighed in a mass on platform scales. The bell-crank, which formed the scale-beam, was balanced when there was no weight in the scale.

The floor and walls of the wheel-pit were water-tight. The leakage at the weir, if any, was too small to be taken account of.

TABLE II.

Coefficients of Useful Effect for several heights of Speed Gate, and Velocities of wheel, deduced from the Experiments made on the Seventy-two inch Swain Turbine Water Wheel, in Boott Cotton Mill No. 5, in August, 1874.

Height of opening of Speed Gate, Inches.	Coefficients of Useful Effect; the Ratio of the Velocity of the Exterior Circumference of the wheel to the Velocity due the head acting on the wheel, being as given in the headings of the several columns.																				
	0·60	0·61	0·62	0·63	0·64	0·65	0·66	0·67	0·68	0·69	0·70	0·71	0·72	0·73	0·74	0·75	0·76	0·77	0·78	0·79	0·80
13·06 Full Gate	0·765	0·771	0·776	0·782	0·788	0·793	0·798	0·803	0·808	0·813	0·818	0·822	0·827	0·830	0·832	0·834	0·835	0·835	0·834	0·833	0·831
12·00	0·775	0·781	0·786	0·791	0·796	0·802	0·807	0·811	0·816	0·820	0·824	0·828	0·832	0·835	0·837	0·838	0·839	0·838	0·837	0.836	0·831
11·00	0·775	0.781	0·786	0·792	0·797	0·802	0·807	0·812	0·817	0·821	0·825	0·829	0·831	0·833	0·833	0·832	0·830	0·827	0·824	0·819	0·815
10·00	0·782	0·788	0·794	0·800	0·805	0·810	0·815	0·820	0·824	0·828	0·831	0·833	0·834	0·834	0·833	0·831	0·828	0·824	0·820	0·814	0·809
9·00	0·779	0·785	0·791	0·797	0·803	0·808	0·812	0·816	0·820	0·823	0·825	0·827	0·828	0·827	0·825	0·823	0·820	0·815	0·811	0·806	0·800
8·00	0·771	0·777	0·783	0·788	0·793	0·797	0·800	0·802	0·804	0·805	0·806	0·807	0·806	0·805	0·803	0·800	0·796	0·795	0·791	0·788	0·783
7·00	0·764	0·769	0·774	0·778	0·781	0·784	0·787	0 788	0·790	0·790	0·790	0·790	0·788	0.786	0·783	0·780	0·777	0·772	0·768	0·763	0·757
6·00	0.742	0·747	0·751	0·754	0·757	0·759	0·760	0·761	0·761	0·760	0·759	0 758	0·756	0·753	0·751	0·747	0·743	0·739	0·734	0·728	0·722
5·00	0·708	0·711	0.714	0·717	0·719	0·721	0·722	0·722	0·721	0·720	0·719	0·718	0·717	0·715	0·713	0·710	0·707	0·704	0·701	0·697	0·693
4·00	0·654	0·658	0·661	0·664	0·666	0·668	0·669	0·669	0·668	0·667	0·665	0·663	0·660	0·657	0·655	0·652	0·648	0·645	0·641	0·637	0·633
3·00	0·576	0·579	0·581	0·583	0·585	0·586	0·586	0·586	0· 85	0 584	0·582	0·580	0·578	0·575	0·571	0·568	0·563	0·559	0·555	0·550	0·545
2·00	0·474	0·474	0·473	0·472	0·471	0·469	0·468	0·463	0·460	0·456	0·451	0·445	0·441	0·434	0·428	0·420	0·412	0·404	0·395	0·385	0·375

The experiments detailed on the accompanying sheets, marked Table I, I think require little explanation beyond what is contained in the headings of the several columns. You will observe that they are not in all cases given in the order in which they were made. The first twenty-two experiments were intended to be a preliminary trial, to ascertain if the testing apparatus operated satisfactorily. When they were made it was supposed that the full opening of the speed-gate was 13·00 inches, and they were intended to be made at quarter, half, and full gate. It was subsequently ascertained that the full opening was 13.08 inches. The remaining experiments were made with special reference to determining the quantity of water discharged at each full inch in height of opening of the speed-gate, from two to twelve inches, and when fully open.

The experiments have been plotted on section paper, and a series of curves drawn for the several heights of gate, for the purpose of interpolation and eliminating irregularities.

Table II has been deduced from these curves; it indicates that from 9 inch gate to 13·08 inch gate, or say from about two-thirds gate to full gate, the maximum coefficient of useful effect varies from 0·828 to 0·839, or about one per cent.; the velocity of the exterior circumference of the wheel relatively to the velocity due the head, corresponding to the maximum coefficient of useful effect, being for 9 inch gate about 0·720, and for full gate about 0·765. At half gate the maximum coefficient of useful effect is about 0·78, at a relative velocity of about 0.68. At one-quarter gate, the maximum coefficient of useful effect is about 0·61 at a relative velocity of about 0·66.

Very respectfully,

[Signed] JAMES B. FRANCIS.

Lowell, Mass., Feb. 24, 1875.

APPENDIX.

DESCRIPTION OF THE SEVENTY-TWO INCH SWAIN TURBINE WATER WHEEL BUILT BY THE SWAIN TURBINE CO., LOWELL, MASS., EXPERIMENTED UPON AT THE BOOTT COTTON MILLS, AUGUST 3–7, 1874.

Plate I represents a vertical section through the centre of the wheel and pit, showing the measuring weir w, and the rack r, and also parts of the weighing apparatus, friction pulley p, brake b, and counterbalancing apparatus c c c c.

Plate II represents a plan of the weighing apparatus and measuring flume with weir and rack.

Plate III represents a vertical section through the centre of the wheel, on a larger scale, with a plan of portions of the wheel and gate, and a development of the outer surface of the wheel.

The lower curb C, is a strong disc of cast iron, with a short cylinder upon which the gate moves, and an inner tube with diverging sides, through which the water leaving the wheel is discharged into the pit. There are three arms reaching from the sides of this tube to the hub which forms the pintle upon which the wheel revolves. The step S is a cylinder of white oak, with conical ends, and is free to revolve with the wheel or to remain stationary upon the pintle while the wheel revolves around it. By means of pipe (*f*) water is supplied to the step, passing through its centre and escaping outward over its ends. The intermediate piece a a connecting the shaft c and the wheel coupling v, can be removed to replace the step, without disturbing either the wheel or shaft. The screws t t in the flange of the shaft, are used to adjust the wheel vertically.

The gate G was made with two cylinders, N and M, attached at their tops to a disc Q, which forms an angle of 80° with the cylinders. At the lower end of the outer cylinder is a narrow flange to which is fastened the leather packing, which prevents the escape of water between the gate and the lower curb. This gate has 24 guides, 3 of them being of cast iron, and of the form shown in the plan at e, Plate III. The other guides, 21 in number, are of bronze 0·23 inch in thickness and 18·94 inches long. These are sharpened at each end to 0·04 inch in thickness, with a bevel on each side one inch long; and are so set as to form an angle of 14° with the tangent to the wheel passing through their inner edges.

Outside of, and in a line with, the thick guides, are placed three stands, one of which is seen at o, Fig. 1, Plate III. These support the chamber E, and the wheel cover L. The lower disc of this chamber is slotted, so that the guides may enter the chamber when the gate is raised, by means of the hoisting rods which pass through the thick guides. The plates represent the gate fully opened. The gate is opened by lowering, and closed by raising it, so that when the gate is first opened, the water is admitted into the wheel, immediately under the crown, and the depth of the section of the stream passing through the guides, is increased in proportion as the gate is opened. The lower edge of the chamber, and the upper edge of the gate, are finished so as to form a close joint when brought into contact. The inner edges of the guides are 1⅛ inches distant, radially, from the outer edges of the buckets.

The wheel W, is 72 inches in diameter at the outer edges of the buckets, and 23·35 inches in depth from the under side of crown to the lower edge of the band. It has 25 buckets of bronze, these being formed between dies in a press, and having the crown plate and the lower band cast upon them of iron.

Fig. 2, Plate III, is a horizontal section just below the crown plate, and represents the form of the bucket for the first six inches below the crown.

Fig. 3 is a development of a portion of the cylindrical surface of the wheel containing the outer edges of the buckets. The discharging edge of the bucket lies in a vertical plane passing through the axis of the wheel, and is parallel to this axis, from the under side of the crown, to a point about 8½ inches below it, and from this point is continued in the form of a quadrant having a radius equal to one-fifth of the diameter of the wheel, and having its centre in the cylinder forming the outer circumference of the wheel. Thus forming, in connection with the surface of the adjoining bucket, an outlet which is in effect a union of two wheels, an inward discharge, and a downward discharge.

The following measurements were made at the mill, before the wheel was started:

Vertical distance from under side of crown to the lower edge of the buckets,	23·35	inches.
Vertical distance from the under side of crown to the top of band B,	13·285	"
Total area of outlets of wheel (25 in number),	9·558	square feet.
Vertical movement of speed gate,	13·08	inches.
Mean shortest distance from the inner edge of one guide to side of adjacent guide (24 in number),	4·532	"
Total area of inlet in speed gate,	9·880	square feet.

ON THE MOMENTS AND REACTIONS OF CONTINUOUS GIRDERS.

By MANSFIELD MERRIMAN, C. E.,

Instructor in Civil Engineering in the Sheffield Scientific School.

(Continued from Vol. lxix, page 215.)

The laws by which the tables of the preceding article may be extended can be stated in algebraic language. The numbers which follow the law for Case I, I shall designate by the letters b_1, b_2, b_r, etc., referring to them in general as the series b. The numbers following the law for the other cases will be represented in the same way by the letters c_2, c_3, c_r, etc. In the discussion of these series it

will be convenient and necessary that the signs of the numbers should be alternately positive and negative, as shown in the following table:

(1)

Series b.	Series c.*
$0 = b_1$	$0 = c_1$
$1 = b_2$	$1 = c_2$
$1 = b_3$	$-4 = c_3$
$-3 = b_4$	$15 = c_4$
$-4 = b_5$	$-56 = c_5$
$11 = b_6$	$209 = c_6$
$15 = b_7$	$-780 = c_7$
$-41 = b_8$	$2911 = c_8$
$-56 = b_9$	$-10864 = c_9$
$153 = b_{10}$	$40545 = c_{10}$
$209 = b_{11}$	$-151316 = c_{11}$
$-571 = b_{12}$	$564719 = c_{12}$
$-780 = b_{13}$	etc.
$2131 = b_{14}$	
etc.	

The first of these series which follows numerically the law for Case I is represented by the following equations:

(2)

$$
\begin{aligned}
b_2 &= 1 \\
b_2 - b_3 &= 0 \\
b_2 + 2b_3 + b_4 &= 0 \\
-b_3 + b_4 - b_5 &= 0 \\
b_4 + 2b_5 + b_6 &= 0 \\
-b_5 + b_6 - b_7 &= 0 \\
* \quad * \quad * \quad * \quad * \quad * & \\
b_m + 2b_{m+1} + b_{m+2} &= 0 \\
-b_{m+1} + b_{m+2} - b_{m+3} &= 0
\end{aligned}
$$

where the index m is an *even* number. The second series is represented by the equations:

(3)

$$
\begin{aligned}
c_2 &= 1 \\
4c_2 + c_3 &= 0 \\
c_2 + 4c_3 + c_4 &= 0 \\
c_3 + 4c_4 + c_5 &= 0 \\
* \quad * \quad * \quad * \quad * & \\
c_r + 4c_{r+1} + c_{r+2} &= 0
\end{aligned}
$$

* The numbers composing this series are usually called the Clapeyronian numbers, because first used by Clapeyron, the inventor of the theorem of three moments. (See *Comptes Rendus*, 1857, Vol. xlv, p. 1076.)

In the first of these series, if we eliminate all the numbers with even indices, we have:

$$\begin{aligned} b_3 &= 1 \\ 4b_3 + b_5 &= 0 \\ b_3 + 4b_5 + b_7 &= 0 \\ * \quad * \quad * \quad * \quad * \quad * \quad * & \\ b_{m-1} + 4b_{m+1} + b_{m+3} &= 0 \end{aligned}$$

Hence the numbers with an odd index in the series b are the same as those of the series c.

Eliminating all the numbers with an odd index we have:

$$\begin{aligned} b_2 &= 1 \\ 3b_2 + b_4 &= 0 \\ b_2 + 4b_4 + b_6 &= 0 \\ b_4 + 4b_6 + b_8 &= 0 \\ * \quad * \quad * \quad * \quad * & \\ b_m + 4b_{m+2} + b_{m+4} &= 0 \end{aligned} \tag{4}$$

Hence all even b's, except b_4, follow the same law as the series c.

If we subtract the alternate numbers composing the series b, a new series may be formed, which will be designated by the letter d, thus:

$$\begin{aligned} b_3 - b_1 &= d_2 \\ b_4 - b_2 &= d_3 \\ b_5 - b_3 &= d_5 \\ * \quad * \quad * \quad * & \\ b_{r+1} - b_{r-1} &= d_r \end{aligned} \tag{5}$$

From which we may deduce the equations for d,

$$\begin{aligned} d_2 &= 1 \\ 4d_2 + d_3 &= 0 \\ -d_2 + d_3 - d_4 &= 0 \\ d_3 + 2d_4 + d_5 &= 0 \\ * \quad * \quad * \quad * \quad * \quad * & \\ -d_m + d_{m+1} - d_{m+2} &= 0 \\ d_{m+1} + 2d_{m+2} + d_{m+3} &= 0 \end{aligned} \tag{6}$$

Multiplying together (2) and (6), equation by equation, and reducing, we have:

$$
\begin{aligned}
b_2 d_2 &= 1 \\
4b_2 d_2 + b_3 d_3 &= 0 \\
b_3 d_2 + 4b_3 d_3 + b_4 d_4 &= 0 \\
b_3 d_3 + 4b_4 d_4 + b_5 d_5 &= 0 \\
* \quad * \quad * \quad * \quad * \quad * & \\
b_r d_r + 4b_{r+1} d_{r+1} + b_{r+2} d_{r+2} &= 0
\end{aligned} \tag{7}
$$

Therefore $b_2 d_2 = c_2$, $b_3 d_3 = c_3$, $b_r d_r = c_r$; or generally

$$b_r (b_{r+1} - b_{r-1}) = c_r \tag{8}$$

Designating by Σc_r the sum of the series c as far as and including c_r we have $\Sigma c_r - \Sigma c_{r-1} = c_r = b_r b_{r+1} - b_r b_{r-1}$, and since this is true for all values of r, we have the important relation:

$$\Sigma c_r = b_r b_{r+1} \tag{9}$$

Further it is evident that if all the numbers of the series c be multiplied by the same number, the resultant series will follow the same law. Also, if there be two series, each following the same law as c, the sums of the corresponding numbers will be similar series. The same of course holds true for b.*

---

* Many other interesting properties of these series might be deduced, but the above are all that are absolutely required for the purposes of the present paper. A few of the most important are here noted as matters of general interest.

By the addition of equations (3) we get the sum of the first r Clapeyronian numbers,

$$\Sigma c_r = \tfrac{1}{6}(c_r - c_{r+1} + 1).$$

The ratios $\frac{c_2}{c_3}, \frac{c_3}{c_4}, \frac{c_4}{c_5}, \ldots \frac{c_r}{c_{r+1}}$, are comprised within very narrow limits; $\frac{c_2}{c_3} = 0{\cdot}25$, and when r is infinite, $\frac{c_r}{c_{r+1}} = 0{\cdot}26795$. The following formula gives c_n in terms of c_{n-1}:

$$c_n = 2c_{n-1} + \sqrt{3c^2_{n-1} + 1}; \text{ or approximately } c_n = 3{\cdot}732 c_{n-1}.$$

The relation $c_r c_n - c_{r-1} c_{n-1} = c_{n+r-2}$ is useful in the reduction of complex expressions. The ratios $\frac{c_2}{b_5 - b_3}, \frac{c_3}{b_7 - b_5}, \ldots \frac{c_r}{b_{2r+1} - b_{2r-1}}$, which give the inflection points in the unloaded spans, are included between the narrow limits 0·2 and 0·21133. The sum of the first m numbers in the series b is

$$\Sigma b_m = \tfrac{1}{2}(b_m + 1);$$

and the sum of the first $m+1$ numbers is

$$\Sigma b_{m+1} = -\tfrac{1}{2}(b_{m+2} - 1);$$

m being an *even* number.

The Theorem of Three Moments for continuous girders whose supports are on the same level is for concentrated loads,

$$(10)\quad M_{r-1}l_{r-1}+2M_r(l_{r-1}+l_r)+M_{r+1}l_r=\frac{P_r}{l_r}(2l^2_r a-3l_r a^2+a^3)$$
$$+\frac{P_{r-1}}{l_{r-1}}(l^2_{r-1}a-a^3)$$

and the reaction at the rth support is:

$$(11)\quad R_r=\frac{M_r-M_{r-1}}{r-1}+\frac{M_r-M_{r+1}}{l_r}+\frac{P_r}{l_r}(l_r-a)+\frac{P_{r-1}}{l_{r-1}}a;$$

where a is the distance of each load from the nearest left hand support.*

When all the spans are equal we have from (10) and (11),

$$(12)\quad M_{r-1}+4M_r+M_{r+1}=Q+Q'.$$

$$(13)\quad R_r=\frac{1}{l}(2M_r-M_{r-1}-M_{r+1})+q+q'$$

where Q, q, etc., denote the terms involving P. When the load is uniform, $P=wda$, and the corresponding values of these functions are easily obtained by integration between the limits $a=0$ and $a=l$.

Putting $\frac{a}{l}=k$, we have the following values:

For a uniform load,

$$(14)\quad Q=Q'=\tfrac{1}{4}wl^2;\ q=q'=\tfrac{1}{2}wl.$$

For a concentrated load,

$$(15)\quad Q=Pl(2k-3k^2+k^3);\ Q'=Pl(k-k^2).$$
$$q=P(1-k);\ q'=Pk.$$

Formula (12) can be applied to all the supports except the two abutments where the moments are zero. Hence if there be s spans we have $s-1$ equations for the determination of the $s-1$ unknown moments. The reactions can then be found by writing $s+1$ equations of the form of (13), and introducing the values of the moments.

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* For the demonstration of these important theorems, see *La Mécanique Appliquée*, Vol. III, by Bresse, or *Theorie der continuirlichen Träger*, by Weyrauch.

Thus, if there be six spans all uniformly loaded, the equations of moments are

$$\begin{aligned} 4M_2+M_3&=2Q \\ M_2+4M_3+M_4&=2Q \\ M_3+4M_4+M_5&=2Q \\ M_4+4M_5+M_6&=2Q \\ M_5+4M_6&=2Q \end{aligned} \qquad (16)$$

and by ordinary algebraic methods the values of M_2, M_3, etc., may be found. When the number of equations is large, however, the algebraic processes become long and tedious, and it is here that the method of *indeterminate multipliers* becomes particularly applicable. By way of illustration I shall apply the method to the above equations. Let the first equation be multiplied by the indeterminate number c_2, the second by c_3, the third by c_4, etc., and then let all the equations be added together, we have

$$M_2(4c_2+c_3)+M_3(c_2+4c_3+c_4)+M_4(c_3+4c_4+c_5)+M_5(c_4+4c_5+c_6) \\ +M_6(c_5+4c_6)=2Q(c_2+c_3+c_4+c_5+c_6).$$

Now, in order to obtain M_6, we have only to require such relations to exist between the indeterminate multipliers that all the other terms in the left hand member of the equation shall become zero. This gives us the equations of the multiplier.

$$\begin{aligned} 4c_2+c_3&=0 \\ c_2+4c_3+c_4&=0 \\ c_3+4c_4+c_5&=0 \\ c_4+4c_5+c_6&=0 \end{aligned} \qquad (17)$$

and the values of c_2, c_3, etc., will at once determine M_6.

$$M_6=2Q\frac{c_2+c_3+c_4+c_5+c_6}{c_5+4c_6}. \qquad (18)$$

The values of c may be perfectly arbitrary, provided only that they satisfy the above equations. Following the practice of Clapeyron, it is usual to take c_2 as unity, hence we have from equations (17)

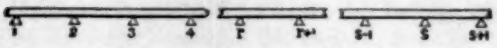
$$c_2=1. \quad c_3=-4. \quad c_4=15. \quad c_5=-56. \quad c_6=209.$$

Substituting these values in (18) we have

$$M_6=2Q\frac{165}{780}=\frac{11}{104}wl^2.$$

The other moments are now easily obtained direct from (16), thus

$$M_5 = 2Q - 4M_6 = \frac{8}{104} wl^2, \text{ etc.}$$



Let us now apply this method to a girder of s equal spans uniformly loaded; the equations of moments are

$$\begin{aligned}
4M_2 + M_3 &= 2Q \\
M_2 + 4M_3 + M_4 &= 2Q \\
M_3 + 4M_4 + M_5 &= 2Q \\
&* \quad * \quad * \quad * \\
M_{r-1} + 4M_r + M_{r+1} &= 2Q \qquad (19) \\
&* \quad * \quad * \quad * \\
M_{s-2} + 4M_{s-1} + M_{s+1} &= 2Q \\
M_{s-1} + 4M_s &= 2Q
\end{aligned}$$

And the corresponding multipliers are

$$c_2, c_3, c_4, \quad * \quad * \quad * \quad * \quad c_r, \quad * \quad * \quad * \quad * \quad c_{s-1}, c_s.$$

Hence we have at once

$$M_s = 2Q \frac{c_2 + c_3 + c_4 + \ldots . c_r + \ldots . c_{s-1} + c_s}{c_{s-1} + 4c_s}.$$

The numerator in the second member may be designated as Σc_s, and the denominator is equal to $-c_{s+1}$, since $c_{s-1} + 4c_s + c_{s+1} = 0$. Hence

$$M_s = -2Q \frac{\Sigma c_s}{c_{s+1}};$$

but from (8) and (9) we have $c_{s+1} = b_{s+1}(b_{s+2} - b_s)$ and $\Sigma c_s = b_s b_{s+1}$, therefore

$$M_s = -2Q \frac{b_s}{b_{s+2} - b_s}.$$

Since the girder is symmetrical with respect to its centre, we must also have

$$M_2 = M_s = -2Q \frac{b_s}{b_{s+2} - b_s}, \qquad (20)$$

a result which might be found by changing the order of the multiplier, that is, multiplying the first equation by c_s, the second by c_{s-1}, the rth by c_{s-r+2}, the $s-1$th by c_3, etc., and deducing M_2 by exactly the same processes as given for M_s.

From (19) we find the other moments in terms of M_2,

$$\begin{aligned} M_3 &= \quad 2Q - 4M_2 \\ M_4 &= -\ 6Q + 15M_2 \\ M_5 &= \quad 24Q - 56M_2 \end{aligned}$$

or universally,

$$M_r = 2Q\Sigma c_{r-1} + c_r M_2.$$

Substituting the values $\Sigma c_{r-1} = b_{r-1}b_r$ and $c_r = b_r(b_{r+1} - b_{r-1})$ from (8) and (9), we have after reduction,

$$(21) \qquad M_r = 2Q\, b_r \frac{b_{r-1}b_{s+2} - b_{r+1}b_s}{b_{s+2} - b_s}.$$

If there be $s+1$ spans we find in exactly the same way,

$$M_r = 2Q\, b_r \frac{b_{r-1}b_{s+3} - b_{r+1}b_{s+1}}{b_{s+3} - b_{s+1}}.$$

Therefore the numerators and denominators of the coefficients of Q *follow the law of the series* b, and since b_{s+2} and b_s have different signs, as do also b_{r-1} and b_{r+1}, the sign of the fractional part of this coefficient will be the same as the sign of b_r. The moment M_r will then always be positive. Hence the moments follow the law as given for Table A.

A similar proof may be made out for the reactions in *Case I.* From (21) we have M_r, M_{r-1}, and M_{r+1}; substituting these in (13), and putting $q' = q$, we have, after reductions by equations (8) and (9),

$$(22) \qquad R_r = q\frac{6b_r(b_{r-1}b_{s+2} - b_{r+1}b_s) + b_{s+2} - b_s}{b_{s+2} - b_s}.$$

Hence the reactions also follow the law of the series b, and since this expression can be placed under the form,

$$(23) \qquad R_r = 6\frac{M_r}{l} + q,$$

we see that the reactions are always positive. This expression, however, fails for the abutments, since it is deduced under the supposition

that the load exists on both sides of the support. For the abutments we have from (13), by placing $r=1$ and $r=s+1$,

$$R_1=-\frac{M_2}{l}+q, \text{ and } R_{s+1}=-\frac{M_s}{l}+q,$$

and reducing by the substitution of M_2 and M_s from (18), remembering that $2Q=ql$, we have

$$R_1=R_{s+1}=q\frac{b_{s+2}}{b_{s+2}-b_s}, \tag{24}$$

an expression which must be always positive, since b_{s+2} is greater than b_s.

For *Cases II* and *III* I shall suppose the load to be in the rth span of the girder. The equations of moments will be,

$$\begin{array}{lll}
c_2 & 4M_2+M_3=0 & c_s \\
c_3 & M_2+4M_3+M_4=0 & c_{s-1} \\
c_4 & M_3+4M_4+M_5=0 & c_{s-2} \\
 & * \quad * \quad * \quad * \quad * & \\
c_r & M_{r-1}+4M_r+M_{r+1}=Q & c_{s-r+2} \\
c_{r+1} & M_r+4M_{r+1}+M_{r+2}=Q' & c_{s-r+1} \\
 & * \quad * \quad * \quad * \quad * & \\
c_{s-1} & M_{s-2}+4M_{s-1}+M_s=0 & c_3 \\
c_s & M_{s-1}+4M_s=0 & c_2
\end{array} \tag{25}$$

where the series c, which is written on the left, gives the multipliers for determining M_s, while those on the right serve to find M_2. Q and Q′ representing in general two different functions of the load, we have

$$M_2=-\frac{Qc_{s-r+2}+Q'c_{s-r+1}}{c_{s+1}},$$

$$M_s=-\frac{Qc_r+Q'c_{r+1}}{c_{s+1}}. \tag{26}$$

From (25) we have

$$M_3=-4M_2$$
$$M_4=15M_2, \text{ etc.}$$

Or universally, if m be less than or equal to r,

$$(27) \qquad M_m = c_m M_s = -c_m \frac{Q c_{s-r+2} + Q' c_{s-r+1}}{c_{s+1}},$$

and if m be equal to or greater than $r+1$,

$$(27) \qquad M_m = -c_{s-m+2} \frac{Q c_r + Q' c_{r+1}}{c_{s+1}}.$$

Hence we see that the moments follow the law of Clapeyron's numbers.

For the abutment reactions we have from (13)

$$(28) \qquad \text{when } r=1,\ R_1 = -\frac{M_2}{l} + q;\ \text{when } r=s,\ R_{s+1} = -\frac{M_s}{l} + q;$$

$$\text{when } r>1,\ R_1 = -\frac{M_2}{l};\ \text{when } r<s,\ R_{s+1} = -\frac{M_s}{l}.$$

For the other reactions, except those at the supports adjacent to the loaded span, we have from (13)

$$(29) \qquad R_m = \frac{1}{l}(2M_m - M_{m-1} - M_{m+1}), \text{ or from (27)}$$

$$R_m = \frac{M_2}{l}(2c_m - c_{m-1} - c_{m+1});$$

but from (3) we have $-c_{m-1} - c_{m+1} = 4c_m$; hence

$$(30) \qquad R_m = 6c_m \frac{M_2}{l} = 6\frac{M_m}{l}.$$

For the reactions at the supports adjacent to the loaded span (when they are not abutment reactions) we substitute (27) in (13) and obtain after reduction,

$$(31) \qquad R_r = 6\frac{M_r}{l} - \frac{Q}{l} + q,$$

$$R_{r+1} = 6\frac{M_{r+1}}{l} - \frac{Q'}{l} + q'.$$

Therefore the reactions likewise follow the same law.

It will be noticed that all the tables given in the first part of this article are here presented in terms of a few constants, and the two series, b and c. Formulæ (21), (23), and (24) give the moments and reactions for the case when the whole girder is uniformly loaded, and (27) to (31) for the case when a single span only is loaded, while

the constants are given by (14) and (15). The formulæ are simple and not difficult of application, and may perhaps by some be preferred to the tables. The tables, however, present the quantities more clearly to the eye, and can be readily used by those unfamiliar with the reduction of algebraic expressions.

When the end spans are of different lengths from the others, the above method is also with slight modifications applicable. Suppose such a girder to be loaded in the rth span, and let the lengths of the first and last span be designated by nl, the second and last but one by pl, the others as before by l. Referring to (10) and (11) the functions of the load now become:

(32) For a uniform load.

$$\begin{cases} \text{when } r=1 \text{ or } r=s;\ Q=Q'=\tfrac{1}{4}wn^3l^2. \\ \qquad\qquad q=q'=\tfrac{1}{2}wnl. \\ \text{when } r=2 \text{ or } r=s-1;\ Q=Q'=\tfrac{1}{4}wp^3l^2. \\ \qquad\qquad q=q'=\tfrac{1}{2}wpl. \\ \text{when } r>2 \text{ or } r<s-1;\ Q=Q'=\tfrac{1}{4}wl^2. \\ \qquad\qquad q=q'=\tfrac{1}{2}wl. \end{cases}$$

(33) For a single concentrated load.

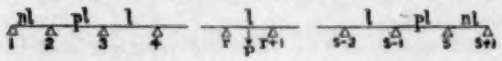
$$\begin{cases} \text{when } r=1 \text{ or } r=s;\ Q=Pn^2l\,(2k-3k^2+k^3).\quad Q'=Pn^2l\,(k-k^3). \\ q=P\,(1-k).\quad q'=Pk.\quad k=\dfrac{a}{nl}. \\ \text{when } r=2 \text{ or } r=s-1;\ Q=Pp^2l\,(2k-3k^2+k_3).\quad Q'=Pp^2l\,(k-k^3). \\ q=P\ (1-k).\quad q'=Pk.\quad k=\dfrac{a}{pl}. \\ \text{when } r>2 \text{ or } r<s-1;\ Q=Pl\,(2k-3k^2+k^3).\ Q'=Pl\,(k-k^3). \\ q=P(1-k).\quad q'=Pk.\quad k=\dfrac{a}{l}. \end{cases}$$

and the equations of moments are:

$$\begin{aligned} 2M_2\,(p+n)+M_3p&=0 \\ M_2p+2M_3(p+1)+M_4&=0 \\ M_3+4M_4+M_5&=0 \end{aligned}$$

* * * *

(33)
$$\begin{aligned} M_{r-1}+4M_r+M_{r+1} &= Q \\ M_r+4M_{r+1}+M_{r+2} &= Q' \\ * \quad * \quad * \quad * \\ M_{s-2}+2M_{s-1}(1+p)+M_s p &= 0 \\ M_{s-1}p+2M_s(p+n) &= 0 \end{aligned}$$



Multiplying these by the indeterminate quantities c_2, c_3, c_r, etc., we get at once the values of M_2 and M_s:

(34)
$$M_2 = \frac{Qc_{s-r+2}+Q'c_{s-r+1}}{pc_{s-1}+2(p+n)c_s}$$
$$M_s = \frac{Qc_r+Q'c_{r+1}}{pc_{s-1}+2(p+n)c_s}.$$

And the equations of condition for the multipliers will be:

(35)
$$\begin{aligned} 2(p+n)c_2+pc_3 &= 0 \\ pc_2+2(p+1)c_3+c_4 &= 0 \\ c_3+4c_4+c_5 &= 0 \\ * \quad * \quad * \quad * \\ c_r+4c_{r+1}+c_{r+2} &= 0 \end{aligned}$$

As before it will be most convenient to assume $c_2 = 1$; then from (35) we have:

(36)
$$\begin{aligned} c_1 &= 0 \\ c_2 &= 1 \\ c_3 &= \frac{-2p-2n}{p} \\ c_4 &= \frac{p(4+3p)+n(4+4p)}{p} \\ c_5 &= \frac{-p(14+12p)-n(14+16p)}{p} \\ c_6 &= \frac{p(52+45p)+n(52+60p)}{p} \end{aligned}$$

* etc., etc.,

by which the values of M_2 and M_3 may be found for any number of spans, the load being in any assigned span r.

Since equations (33) and (35) are of the same form,

$$M_3 = c_3 M_2, \quad M_4 = c_4 M_2,$$

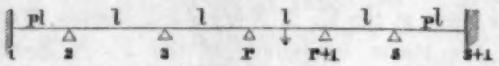
or universally,

$$(37) \qquad \text{when } m < r+1; \quad M_m = c_m \frac{Qc_{s-r+2} + Q'c_{s-r+1}}{pc_{s-1} + 2(p+n)c_s},$$

$$\text{when } m > r; \quad M_m = c_{s-m+2} \frac{Qc_r + Q'c_{r+1}}{pc_{s-1} + 2(p+n)c_s}.$$

The laws for the reactions are the same as those for equal spans when $m > 3$, or $m < s-1$. For other values of m they are best found by the general formula (11), by placing q and q' for the terms containing P, remembering that q corresponds to a load on the span following the support considered, and q' to a load on the span preceding.

If in the foregoing expressions we make $n = 0$, the points 1 and 2 fall together, and the reactions at those points become infinite and opposed. This is the mathematical condition for fastened ends, that is, ends where the tangent to the elastic curve is horizontal. Expressions (32) to (37) will therefore give all the moments for girders with walled in ends, when all the spans are equal, or when the spans nearest to the ends are different in length. Making $n = 0$, and changing the indices so that they correspond with the sketch, we



have for the moments

$$(38) \qquad \text{when } m < r+1, \quad M_m = c_{m-1} \frac{Qc_{s-r+1} + Q'c_{s-r}}{pc_{s-1} + 2pc_s},$$

$$\text{when } m > r, \quad M_m = c_{s-m+1} \frac{Qc_{r-1} + Q'c_r}{pc_{s-1} + 2pc_s},$$

where Q and Q′ are given in (32) and (33), and the values of c are,

$$c_0 = 1, \; c_1 = -2, \; c_2 = 4+3p, \; c_3 = -14-12p, \; c_4 = 52+45p, \text{ etc.}$$

From these simple formulæ it is easy to get the values of the moments for any girder whose ends are fastened. These values can also be arranged in triangles, since they follow the same laws as for

free ends. From what has been said concerning the reactions the reader can have no trouble in determining them also. For example, making $s = 1$, we have a simple girder.

From (38) we get at once the moments, $M_1 = Pl(k - 2k^2 + k^3)$, $M_2 = Pl(k^2 - k^3)$. From (11) $R_1 = 3\frac{M_1}{l} - \frac{Q}{l} + q$, and $R_2 = 3\frac{M_2}{l} - \frac{Q'}{l} + q'$, or $R_1 = P(1 - 3k^2 + 2k^3)$, and $R_2 = P(3k^2 - 2k^3)$, the well-known expressions for that case. For uniform load in a single span it is only necessary to use the corresponding values of Q and Q'. When there are many spans uniformly loaded, the values due to each loaded span should be found and the results added.

COMPOUND AND NON-COMPOUND ENGINES, STEAM-JACKETS, ETC.

By Charles E. Emery, C. E., New York.

Herewith is presented a discussion of the results of experiments made at Baltimore, Md., in May, 1874, with the steam machinery of the U. S. Coast Survey steamer "Bache," under the general direction of the writer (see vol. lxix, page 105), and of the results of experiments made at the U. S. Navy Yard, Boston, Mass., in August, 1874, with the steam machinery of the U. S. Revenue steamers "Rush," "Dexter," and "Dallas," under the general direction of Chief Engineer Charles A. Loring, U. S. N., and the writer. (See vol. lxix, page 197. See also page 161, showing the tank used for measuring the feed-water during the experiments with the "Bache.")

The detailed reports have been published at different times, and necessarily involve so many details that we add, as convenient for reference from time to time as we proceed with the discussion, a recapitulation of the distinguishing features of the engines tested, and of the general scope of the two series of investigations.

Both series of trials were made with the vessels secured to the dock.

1. The Coast Survey steamer Bache was provided with a compound engine of the steepled type (that is, the smaller cylinder was arranged

above the other, and the pistons had a common rod). The larger cylinder was steam-jacketed, and so arranged that it could be operated independently, using steam of the same pressure and with the same degree of expansion as when both cylinders were working together as a compound engine. Trials were made of the two systems of working, both with the steam-jacket in use and when the same was disconnected, and the amount of water collected from the jackets and intermediate chamber was separately weighed and noted. All the experiments except one, were made with an approximate steam pressure of 80 pounds, and with different degrees of expansion for each system of working, with and without use of jacket. The indicated power was measured, also the cost of the same in steam (shown by the weight of feed-water used). The evaporative efficiency of the boiler was also determined.

2. One of the revenue steamers, the Rush, was provided with a compound engine, constructed on the "fore and aft" system (that is, the cylinders were at the same level, and in this case the pistons were connected to cranks at right angles). Both cylinders were steam-jacketed. The other two revenue steamers, viz., the Dexter and Dallas, had non-compound engines, with unjacketed cylinders. The compound engine of the Rush was operated in two different runs at the approximate steam pressures of 70 and 40 pounds. The single engine of the Dexter was operated with the same steam pressures and at different degrees of expansion for each pressure. The engine of the Dallas was operated at an approximate steam pressure of 35 pounds, and at different degrees of expansion. The boilers were all substantially alike. The performance was obtained by measuring the indicated power and its cost in steam, as shown by the weight of feed-water used. The evaporative efficiency of the boilers was also ascertained during the longer experiments.

From the two series of experiments may be gathered the following information, viz.:

1. The saving by the use of a steam-jacket on the cylinder of a non-compound engine, and the larger cylinder of a compound engine.*

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* The steam-jacket on the larger cylinder of the steamer Bache, and that on each of the cylinders of the steamer Rush, were supplied with steam in the following manner: steam was first admitted to the cavity in cylinder cover, from which, by means of a pipe leading from the bottom of the cavity, it was conducted to the side jacket, thereby keeping the cavity in cover clear of water. The side and bottom jackets communi-

2. The relative saving that may be obtained by the use of a compound engine, as compared with a single engine, operated at the same or a different steam pressure, or at the same or a different degree of expansion.

3. The probable value of a steam-jacket on the smaller or high-pressure cylinder of a compound engine.

4. The influence which the size of a steam cylinder has upon the economy of fuel.

5. The relative cost of the power, at different steam pressures, in compound and non-compound engines.

6. The most economical point of cut-off for the steam pressures employed.

These subjects are discussed in the order named, and paragraphs to which it may be desirable to refer are designated by letters affixed to the numbers referring to the subjects. The table showing the results of experiments on U. S. Coast Survey steamer Bache will be designated "Table No. 1," and that showing the results of experiments with the Revenue steamers, "Table No. 2."

1. The Advantages of the Steam-Jacket—(1 A). Referring to Table No. 1, and comparing the minimum costs for each method of working, we find that the single cylinder of the Bache when operated without the steam-jacket required (Exp. 13, line 46), 26·247 pounds of feed-water per indicated horse-power per hour, and that with steam-jacket in use there was required (Exp. 16, line 46) but 23·154 pounds, showing that the saving by the use of the steam-jacket on a single cylinder engine worked at its most economical point of cut-off is 11·78 per cent. With more expansion, as shown by comparing the previous experiments for each method of working the jacket produces a greater saving, but the steam is in all cases being cut off too short for maximum economy, as will be discussed hereafter.

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cated, and the water of condensation was blown from latter into the hot well, the flow being regulated by the Engineer to maintain a water level, in a glass gauge, on a small chamber in the drain-pipe.

On the Bache, when operated as a compound engine, the steam for the jacket was taken from bottom of steam-chest of upper cylinder, thereby keeping that drained. When the lower cylinder was operated as a single engine, the steam for jacket was taken from main steam-pipe. On the Rush, the steam for jackets was taken directly from the boiler.

It will be shown, in discussing experiments other than those above mentioned, that the system of draining the steam-chests, as well as the steam-jackets, is of considerable advantage.

(1 B.) When the engine of the Bache was operated as a compound engine, with steam-jacket not in use, experiment 2 shows a cost of 23·036 pounds of water per I. H. P. per hour, and experiment 6 with steam jacket in operation, a cost of 20·332 pounds. The saving in steam by the use of the jacket on the larger cylinder of a compound engine is then shown to be 11·73 per cent.

2. Saving by use of Compound Engine—(2 A.) The minimum cost of the power with the single cylinder of the Bache and steam-jacket in use, experiment 16, is 23·154 pounds, and with engine compounded, and steam-jacket on large cylinder in use, experiment 6, it is 20·332 pounds; so the compound engine was operated with a saving of 12·19 per cent. in this case, as compared with the single engine.

(2 B.) The above experiments were made at the same steam pressure, but with a less degree of expansion in the single engine, the steam being expanded nearly seven times (6·975) in the compound engine, and but little more than five (5·11) times in the single engine. With the steam expanded eight and one-half times (8·57) in the single engine (Exp. 15), the cost is 24·088 pounds using the same steam pressure, so the compound engine shows a saving compared therewith of 15·6 per cent. The difference increases as the expansion is increased in the single engine.

(2 C.) The minimum cost of the power with the single cylinder and steam-jacket not in use, experiment 13, is 26·247 pounds, and with engine compounded, without steam-jacket, experiment 2, it is 23·036 pounds, so without using steam-jackets in either case, the compound engine operated with a saving of 12·23 per cent. as compared with the single engine.

(2 D.) With steam-jacket in use on larger cylinder of compound engine, experiment 6, and not in use on single engine, experiment 13, the costs, as before stated, were respectively 20·332 and 26·247 pounds, showing a saving by the use of the former under conditions stated of 22·54 per cent.

(2 E.) In the experiments with the revenue steamers it will be seen (Table No. 2, line 76, Exp 1 and 3) that the relative costs of the power in the compound engine of the Rush with both cylinders jacketed, and in the single engine of the Dexter, with unjacketed cylinder, were as ·7706 to 1·00, corresponding to a saving by the use of the compound engine with both cylinders jacketed, as compared with an engine with single unjacketed cylinder, of 22·94 per cent., or

practically the same as shown on the Bache with only the larger cylinder of the compound engine jacketed.

(2 F.) Assuming that a steam-jacket on the single cylinder of the Dexter would have reduced the cost in the same proportion that it did in the Bache, viz., 11·78 per cent., the cost of the power in the single cylinder engine which was 29·77 per cent. greater than in the compound engine (Table No. 2, line 74, Exp. 1 and 3) would have been reduced (1·2977 × 11·78 =) 15·29 per cent., and the relative costs would have been as 1 to 1·1448, equivalent to a saving of (1·1448 —1·00 × 100 ÷ 1·1448 =) 12·65 per cent., by the use of the compound engine with jacketed cylinder, as compared with the single engine with jacketed cylinder.

As above stated (2 A), the experiment with the Bache showed a saving of 12·19 per cent. under similar conditions.

The experiments do not furnish conclusive information as to what the relative performances of compound and non-compound engines of larger sizes would be. It seems probable, however, that in such case the compound engine would show still greater advantages.

In the revenue experiments above cited (2 E), the saving of 22 94 per cent. was reduced to 12·65 per cent. (2 F) by assuming that a steam-jacket on the cylinder of a single engine would save as much as it did on the Bache, which is not probable, for the reason that the cylinder of the Dexter was larger than that of the Bache, and it is an evident fact that the ratio of capacity to jacket surface decreases as the size of the cylinder is increased.*

This reasoning would not apply to the experiments made on the Bache with the same engine operated on both systems, but in that case the compound engine was not constructed for maximum economy, while the cylinder used for the single engine was probably as good as could be made. The latter was thoroughly steam-jacketed at sides and in bottom and cover. It also had large cylinder ports, and the minimum amount of space in clearances and passages. Tight pistons were used in all cases.†

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* To settle the question as to the economy of the steam-jacket on a single engine of practically the same size as the compound engine of the Rush, arrangements are being made for a series of trials on a Revenue steamer recently completed, the "Gallatin," which has machinery adapted for the purpose.

† It will be interesting to add that the direct steam connection for the larger cylinder of the Bache was originally designed by the writer as an auxiliary arrangement to be used in case of accident to the other cylinder, and the drawing provided therefor, a pipe of the same size as that for the upper cylinder. The contractors, Messrs. Pusey,

When the engine of the Bache was used as a compound engine, the upper cylinder, though well felted and lagged, was necessarily exposed to more refrigerating influence than in compound engines on the "fore and aft" system. The omission of the steam-jacket on the small cylinder may also have occasioned some slight loss, which subject is discussed hereafter. These disadvantages were considered in the first instance as of less consequence than the saving of space, etc., accomplished by adopting the system in that particular location, but in making a comparison of compound and non-compound engines, it is proper that they should be considered.

Both series of experiments appear to show then that the compound engines were at least not tried at any advantage as compared with the single engines; on the contrary, the indications are that still greater comparative economy would be shown by the compound system in larger engines.

3. VALUE OF SMALL CYLINDER JACKET.—These experiments appear also to corroborate the views held by the writer at the time the engine of the Bache was constructed, (1870), viz., that the steam-jacket on the smaller or high pressure cylinder of a compound engine, working with the ordinary degree of expansion, was, contrary to the views of Rankine on the subject,* of comparatively little value.

(3 A.) The experiments with the compound engine of the Rush, where both cylinders were jacketed, compared with the single engine of the Dexter with unjacketed cylinder showed a saving (see 2 E) of 22·94 per cent., and in experiments on the Bache, the compound engine with jacket on large cylinder showed a saving, compared with single cylinder used without jacket (see 2 D) of 22·54 per cent., so the additional jacket on the small cylinder of the Rush did not sensibly affect the comparison on this basis.

(3 B.) On the Bache we find that the saving by the use of a compound engine with large cylinder jacketed, as compared with a single

Jones & Co., of Wilmington, Del., voluntarily increased the size of this pipe so that the two systems could be fairly tested in the same apparatus, though the duties of the vessel were such that it was not convenient to make the trial till about 3½ years after. This same firm, shortly after the construction of the Bache, built also the first of the long stroke high-pressure engines which revived the interest in that system, and I observe that they applied the steam-jacket to the cylinder and connected the cylinder to frames, through legs cast on former to hinder the transmission of heat to latter, the same as was provided for in drawings furnished for the engine of the Bache.

* Rankine on "The Steam Engine," Art. 286.

cylinder used with jacket, is (see 2 A) 12·19 per cent., and by indirectly comparing the performance of the Bache and the revenue steamers, the compound engine of the Rush with both cylinders jacketed, shows a saving (see 2 F) of 12·65 per cent. The saving by the jacket on the small cylinder could not then be more than (12·65 —12·19 =) 0·46 per cent.

(3 BB.) It is probable, however, that in compound engines constructed on the "fore and aft" system, the steam-jackets on *both* cylinders heat the intermediate steam as it passes from one cylinder to the other, and thereby reduce the cost of the power.

(3 C.) The opinion as to the relative value of the steam-jackets on the two cylinders of a compound engine was founded upon the views of the writer expressed in print as early as 1866–7,* which were in substance, that the great difference between the theoretical and practical performances of the steam-engine could be satisfactorily accounted for by the differences of temperature to which the interior surfaces of the cylinder are practically subjected. The metal of the cylinder is cooled by the exhaust steam and must be reheated during the next stroke, which causes condensation of part of the incoming steam; the resulting water is re-evaporated, partially during the expansive portion of the steam stroke, but mostly during the next exhaust stroke, thereby cooling the cylinder again, and the result is to transfer heat (by the alternate condensation and re-evaporation described) directly to waste in the atmosphere or condenser.†

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* U. S. Patent No. 70,707.

† It had previously been suggested that a portion of the loss could be accounted for in the manner indicated. The writer, after reading the account of Tyndall's experiments, showing the facility with which aqueous vapor radiated and absorbed radiant heat, and finding by calculation that it was necessary to heat and cool the metal of a cylinder during each stroke, but a very small distance below the surface to occasion all the loss observed, became convinced that nearly all the loss could be accounted for in this way, and it occurred to him that if the interior walls of the cylinder were made of non-conducting material, the loss would be greatly reduced. Accordingly experiments were made by the writer in 1866, which have been referred to in several publications. The following brief description appeared in an article on Compound Engines in the *American Artisan* of March 8th, 1871:

"The nature of the loss was proved in the following manner: I constructed two cylinders of like dimensions, one of glass, the other of iron, in such a manner that either could be attached to a valve which regularly admitted steam from a boiler to the cylinder and permitted its exhaust into a condensing coil lying in a tub of water.

A full discussion of this branch of the subject would occupy too much space in this paper. It was considered that the range of temperature in the smaller cylinder of a compound engine is generally less than in the larger cylinder and, moreover, that any heat transferred (so to speak) past the piston of the smaller engine would do useful work in the second cylinder. These views are apparently sustained by the experiments, but it should not be assumed that the jacket is of less value simply because high-pressure steam is used in the smaller cylinder, and that, therefore, a jacket is unnecessary for a high-pressure condensing engine. Quite the contrary is true, for in such case the interior surfaces of the cylinder are exposed to a variation of temperature equal to that in both the cylinders of a compound engine, and the jacket becomes of the greatest importance.

(3 D.) It is probable that the steam-jacket produces economy by drying and superheating the steam near the heated surfaces. If this be done promptly the heat imparted to the steam assists in performing useful work during the expansive portion of the stroke. Even during the exhaust stroke the dry steam near the surfaces of the cylinder will absorb very little heat compared to that required to evaporate particles of water which are always present when no jacket is used. The dry steam can only absorb heat at a rate proportioned to its specific heat, which is less than half that of water. The watery particles will take up both sensible and latent heat, or, for equal weights under actual pressures used, about two thousand times as many heat units as the dry steam. Could the steam in a cylinder be discharged simply saturated or slightly superheated, either by previous superheating or the use of efficient steam-jackets, the loss would be very small. At high expansions this is impracticable. Some water is always present and in its evaporation cools the metal surfaces somewhat, and it is always better to re-supply the heat from the steam-jacket than by condensation of incoming steam, as in the latter case the resulting water of condensation remains in the cylinder and causes increased losses in the manner previously indicated.

"The capacities of the two cylinders were made exactly the same, as was shown by transferring water from one to the other. When put in turn in the condition of a steam-engine cylinder, the iron cylinder used (averaging the experiments) fully twice as much steam as the glass one, shown by the fact that twice the quantity of water came through the condensing coil for the same number of movements of the valve. Steam of the same pressure was used in both cylinders, and the experiments were many times repeated with substantially the same results."

From these considerations it may be inferred that steam-jacketed cylinders would be most efficient if of comparatively small diameter and long stroke, in order to obtain as much surface in proportion to volume as possible; and that for unjacketed cylinders the surface in relation to volume should be reduced as much as possible.

4. Economy of Steam as Influenced by the Size of the Cylinder.—It is a well known fact that large engines are more economical per unit of power furnished than small ones. It is related that Watt was led to his invention of a separate condenser by observing the excessive quantity of steam required to operate a small model engine as compared with that found sufficient for engines of practical sizes—the vacuum being produced in both by admitting the condensing water directly into the steam cylinder. We have heretofore called attention to the fact that Watt, in producing condensation in a separate vessel, only partially overcame the difficulty; steam chilled by the performance of work being such an excellent radiator and absorbent of radiant heat as to cool the interior surfaces of a cylinder, upon reduction of pressure by condensation, even in a separate vessel, to a very material degree, if not to the same extent as if the water were directly admitted to the cylinder.*

The manner in which the loss takes place was discussed under the previous heading, and it is evident that the amount of heat transferred to waste in an unjacketed cylinder will, for a given range of temperature, vary as the amount of metal surface and inversely as the volume of steam exposed to the same. As the size of the cylinder is increased the volume increases in a more rapid ratio than the enclosing surfaces, hence the loss, relative to the unit of volume and power, decreases as the size of the cylinder is increased.†

(4 A.) The minimum cost of the power, using a single engine without a steam-jacket was on the Bache (Table No. 1, Exp. 13, line 45), 26·247 pounds of feed-water per horse-power per hour, and on the Dexter (Table No. 2, Exp. 3, line 53) it was 23·857. Again, on the

* The subject was treated in this manner in a lecture delivered at the Sheffield Scientific School in the winter of 1870–71, which never having been completely written out was not published. See reference to Tyndall experiments with radiant heat in preceding foot-note.

† This statement has been demonstrated by numerous experiments, particularly hose referred to in the foot-note on page 105 of the present volume, and may be confirmed by comparing the results of similar experiments in the two series herein discussed.

Bache, using compound engine and jacket on the larger cylinder, the cost was (Table No. 1, Exp. 6, line 46) 20·332 pounds, and on the Rush (Table No. 2, Exp. 1, line 53) it was 18·384 pounds. The engine of the Bache was smaller than that of either of the other steamers, and, as shown, the cost was in both cases considerably more.* We have already pointed out that the relative performances for different methods of working in one series correspond well with those shown by the other, such, for instance, as the saving of the use of the steam-jacket and the relative economy due to a compound engine, but we now find that the actual costs shown in one series cannot be directly compared with those obtained in the other.

It may be accepted as a general fact that an experiment made with one engine cannot be used directly as a basis of comparison except for engines of similar size operated under similar conditions. The want of general information on this subject has often caused great misapprehension. Engineers have again and again made improper comparisons and often have conscientiously drawn directly opposite conclusions from the same data, when neither side had access to information sufficiently complete to refute the arguments of the other.

(4 B.) Referring to the experiments under discussion we find that the minimum cost of the power with the jacketed cylinder of the Bache, non-compound (Table No. 1, Exp. 16, line 46) was 23·15 pounds of water per horse-power per hour, and that with the unjacketed cylinder of the Dexter (Table No. 2, Exp. 3, line 53) it was but 23·86 pounds. Had there been but these two experiments to compare, many would naturally have held that there was little or no economy in the steam-jacket, and it is only by having the extended series of experiments on the "Bache" with and without the use of jackets on the same cylinder, that we are enabled to prove that there is economy in the use of the jackets; and by comparing experiments with engines of different sizes to show further that the actual performances of different engines are not directly comparable, while the relative performances for each engine, operated under different conditions, are properly comparable with similar relative performances of other engines.

(To be continued.)

* The difference in performance between the Rush and the Bache may also be partially accounted for by the fact that there were steam jackets on both cylinders of the Rush, which were so arranged as to heat the intermediate steam, and thereby cause economy in the manner referred to above at (3 BB.)

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

During the time the writer was chief engineer of the Mare Island navy-yard, he made the experiments hereinafter described with the different screws applied by him to the United States steam-launch No. 4, attached to that yard. These experiments were promptly authorized, on the application of the writer, by Admiral Porter, then at the head of the Navy Department, without whose liberal support they could not have been made.

The machinery of the launch, designed by Mr. William R. Eckhart, the superintendent of machinery at the navy-yard and formerly an engineer in the Navy, was completed in the autumn of 1869, before the arrival of the writer. In the conduct of the experiments, all of which were projected and made by the writer in person, Mr. Eckhart rendered most valuable assistance.

The principal objects of the experiments were to ascertain, 1st. The relative economic propelling efficiency of screws of the same diameter, uniform pitch, and number of blades, but of different fractions of the pitch. 2d. The relative economic propelling efficiency of two-bladed, four-bladed, and Mangin screws, having the same diameter, uniform pitch, and fraction of pitch; in other words, having the same quantity and kind of surface. 3d. The relative economic propelling efficiency of a screw of the same diameter as the others, and having the same fraction of pitch as one of them, but three blades and a greater pitch expanding from the forward to the after edge of the blades. 4th. The relative economic propelling efficiency of this three-bladed screw, converted into a Griffith screw.

To ascertain the foregoing facts, there were to be determined for each screw and for different speeds of vessel with the same screw, the gross-effective indicated horse-powers developed by the engines; the pressure per square inch of pistons required to work the engines *per*

se, or disconnected from the screw; the resistance of the vessel *per se*, by dynamometer; the speed of the vessel; the slip of the screws, and the friction of their respective surfaces on the water. These quantities enable the distribution of the whole power exerted to be accurately computed, and the values of the parts applied to produce the different effects ascertained.

Incidentally to the experiments, the economic vaporization of the boiler with anthracite was ascertained; and the power exerted by the engines to give the three-bladed screw a certain number of revolutions per minute, with the vessel held stationary to the wharf.

Before narrating the experiments, it is necessary to give the following description and dimensions of the hull and machinery employed:

HULL.

The hull is of wood. Its submerged surface is not coppered, but was kept well painted and cleaned during the experiments. With the vessel at the below draught of water (at which the experiments were made), the top of the rail at the bow is 6 feet above the water-line; at the center of the vessel's length, 3 feet 3 inches; and at the stern, 4 feet 3 inches. There is a house on the deck, 6 feet 8 inches wide, 38 feet 9 inches long, and rising, as a mean, 3 feet 9 inches above the top of the rail. The rudder is of metal, and counterbalanced.

Length on load water-line, from forward edge of rabbet of stem to after side of sternpost,		54·40 feet.
Extreme breadth on load water-line,		11·88 feet.
Depth of hull, from load water-line to lower edge of rabbet of keel,	Forward,	2·457 feet.
	Mean,	3·156 feet.
	Aft,	3·855 feet.
Depth of the keel below the lower edge of its rabbet,	Forward,	0·500 foot.
	Mean,	0·729 foot.
	Aft,	0·958 foot.
Load-draught of water from the bottom of the keel,	Forward,	2·957 feet.
	Mean,	3·885 feet.
	Aft,	4·813 feet.

Area of the greatest immersed transverse section at load-draught,	24·98 sq. ft.
Area of the load water-line,	456·54 sq. ft.
Area of the immersed external surface of the hull proper, exclusive of keel and rudder,	603·00 sq. ft.
Area of the immersed external surface of the hull, inclusive of keel (100·8 square feet) and rudder (132 square feet),	717·00 sq. ft.
Displacement, per inch of draught, at load water line,	38·045 cu. ft.
Displacement, per inch of draught, at load water line,	1 0891 ton.
Displacement, to load water-line,	814·100 cu. ft.
Displacement, to load water-line,	23·3053 tons.
Distance of the greatest transverse section abaft the middle of the length of the load water-line,	3·42 feet.
Height of the metacenter above the center of displacement,	4·93 feet.
Depth of the center of displacement below the load water-line,	1·09 feet.
Center of displacement abaft the middle of the length of the load water-line,	2·26 feet.
Angle of dead-rise at the greatest transverse section,	13½ degrees.
Ratio of the area of the greatest immersed transverse section to the area of its circumscribing parallelogram,	0 6663
Ratio of the area of the load water-line to the area of its circumscribing parallelogram,	0·7064
Ratio of the displacement to its circumscribing parallelopipedon,	0·3991
Ratio of the length of the hull on the load water-line to its breadth,	4·5791

In the following table will be found the areas of the greatest immersed transverse sections, areas of water-lines, displacements, and angles at bow and stern, for different water-lines; commencing at the load water-line previously given, and descending by vertical depths of 6 inches. These water-lines, it must be observed, are parallel to the load water-line corresponding to the vessel's draught of water, forward and aft, previously given:

Number of water-line.	Depth, in feet from lower edge of rabbet of keel to water line.		Area of greatest immersed transverse section, from lower edge of rabbet of keel to water-line in square feet.	Area of water-line in square feet.	Displacement, from lower edge of rabbet of keel to water-line, in cubic feet.	Angles of water lines.	
	Forward.	Aft.				Bow	Stern
						°	°
7	2·457	3·855	24·98	456·54	814·100	38	77
6	1·957	3·355	19·04	421·28	593·915	37	56½
5	1·457	2·855	13·26	370·86	395·360	34½	48
4	0·957	2·355	7·93	294·71	228·025	30	35
3	0·457	1·855	3·62	188·16	105·980	19¼	22½
2		1·355	1·25	81·90	20·090	8	11½
1		0·855	0·35	26·04	15·470	4½	3½

From the following dimensions the form of the immersed solid of the hull can be ascertained. They are ordinates to the curves of the water-lines formed by the outside of the planking, and are given in feet from the forward and aft center line of the hull. That line is divided into sixteen equal parts of 3·4 feet each, and the corresponding transverse sections are numbered from 1 at the stem to 17 at the stern; from each point of division a right-angled ordinate is erected on which the dimensions referred to apply.

The water-lines are 6 inches apart, measured vertically. They are not parallel to the rabbet of the keel, but to the surface of the water when the vessel has the draught of water forward and aft as given above. Water-line A is at the water-level, water-line B is 6 inches below A and parallel to it, and so on.

Water lines 6 inches apart vertically, A being at the water-level.	Ordinates, in feet, from the central forward and aft line of the hull to the outside of the planking on each transverse section of the immersed solid of the hull, as numbered below, No. 1 being at the stem and No. 17 at the stern. Distance of the transverse sections apart, 3·4 feet.																
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.	No. 15.	No. 16.	No. 17.
A	0·12	0·72	1·79	2·94	4·02	4·88	5·45	5·76	5·90	5·94	5·90	5·78	5·50	5·08	4·25	2·68	0·20
B	0·12	0·57	1·41	2·50	3·58	4·50	5·24	5·66	5·84	5·90	5·84	5·66	5·26	4·60	3·42	1·75	0·12
C	0·12	0·40	1·06	2·00	3·01	4·00	4·75	5·25	5·54	5·61	5·52	5·22	4·63	3·76	2·47	1·03	0·12
D	0·12	0·25	0·67	1·36	2·18	3·04	3·85	4·50	4·91	5·00	4·82	4·31	3·54	2·60	1·56	0·62	0·12
E	0·12	0·18	0·39	0·75	1·28	1·85	2·44	2·92	3·25	3·34	3·20	2·78	2·20	1·54	0·90	0·42	0·12
F	0·12	0·16	0·24	0·35	0·50	0·68	0·90	1·14	1·40	1·50	1·42	1·25	0·98	0·70	0·46	0·28	0·12
G	0·12	0·12	0·12	0·12	0·12	0·13	0·14	0·21	0·34	0·45	0·48	0·46	0·30	0·30	0·22	0·14	0·12
H	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·13	0·14	0·14	0·13	0·12
I	0·12	0·12	0 12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12	0·12

ENGINES.

There are two direct-acting, non-condensing engines. The cylinders are vertical, and are placed immediately above the crank-shaft, with their connecting-rods working downward. The cylinders rest upon columns supported in turn upon a cast-iron bed-plate, which contains the crank-shaft journals. The valve-chests of the cylinders are placed between the cylinders, back to back. There are two small slide-valves to each cylinder, one at each end, connected in the chest by rods. These valves work with the full pressure of the steam upon their backs, and receive their movement direct from two eccentrics and a Stephenson link. They have no lap on the exhaust side, but sufficient steam-lap to cut off the steam at 0·858 of the stroke of the piston from the commencement when in full gear. In this state the steam is released when the piston has completed 0·96 of its stroke, and the cushioning commences at 0·94 of the stroke. The Stephenson link is connected directly to the head of the valve-stem.

The cranks for the after-cylinder are forged in the crank-shaft. For the forward cylinder there is but one crank; it was forged separately and keyed on, and its pin is overhung. The crank-shaft has three journals, one for the forward cylinder and two for the after cylinder. The thrust-collars are forged on the crank-shaft, and their pillow-block is supported on the engines' bed-plate. There are no collars on the screw or line shafting.

The feed-pump is worked direct from an eccentric on the crank-shaft between the engines. This pump is slightly inclined, is single acting, and the eccentric-rod is articulated to the bottom of the pump-plunger.

The feed-water is fresh, and is carried in a tank; before it enters the boiler, it is passed through a heater supported on the top of the boiler, and has its temperature raised to about 125° Fahrenheit by the exhaust steam. This heater consists of an outer and inner pipe, placed concentrically; the exhaust-steam being within the inner pipe and the feed-water being in the annular space between the two pipes.

The exhaust-steam after passing through the heater is thrown into the chimney of the boiler, and accelerates its draught.

The sides of the cylinder are felted and lagged, also all the steam pipes.

The following are the principal dimensions of the engines, namely:

Number of cylinders, ...	2
Diameter of cylinders, ...	6¾ inches.

Diameter of piston-rod,	$1\frac{1}{8}$ inches.
Stroke of pistons,	8 inches.
Net area of both pistons, exclusive of piston rods,	70·574 sq. in.
Space displacement of both pistons, exclusive of piston-rods,	564·592 cu. in.
Clearance of the pistons,	$\frac{3}{16}$ inch.
Length of steam-port,	4 inches.
Breadth of steam-port,	$\frac{5}{8}$ inch.
Area of steam-port,	$2\frac{1}{2}$ sq. in.
Length of exhaust-port,	4 inches.
Breadth of exhaust-port,	$\frac{7}{8}$ inch.
Area of exhaust-port,	$3\frac{1}{2}$ sq. in.
Space comprised in the clearances and passages of one end of both cylinders,	26·4 cu. in.
Number of crank-shaft journals,	3
Diameter of crank-shaft journals,	$2\frac{1}{2}$ inches.
Length of crank-shaft journals,	$3\frac{1}{4}$ inches.
Diameter of crank-pin journals,	2 inches.
Length of crank-pin journals,	2 inches.
Diameter of cross-head journals,	$1\frac{1}{4}$ inches.
Length of cross-head journals,	$1\frac{1}{4}$ inches.
Area of main guide-gib,	18·28 sq. in.
Diameter of main connecting-rod in the necks,	$1\frac{3}{16}$ & $1\frac{5}{16}$ in.
Length of main connecting-rod between centers of journals,	19 inches.
Diameter of feed-pump (single-acting plunger),	$2\frac{1}{2}$ inches.
Stroke of feed-pump plunger,	$2\frac{1}{2}$ inches.
Width of eccentric-straps,	$\frac{3}{4}$ inch.
Length, forward and aft the vessel, occupied by the engines,	36 inches.
Breadth, athwartship, occupied by the engines,	27 inches.
Height of the engines above axis of crank-shaft,	42 inches.
Number of thrust-collars on screw-shaft,	5
Projection of thrust-collars beyond screw-shaft,	$\frac{7}{16}$ inch.
Thickness of thrust-collars on screw-shaft,	$\frac{1}{2}$ inch.
Heating surface in feed-water heater,	260 sq. in.
Net weight of engines, including crank-shaft, but excluding everything else,	1400 pounds.

BOILER.

There is one boiler of the horizontal fire-tube type, with the tubes returned by the sides of the furnace.

The shell is a horizontal cylinder of 49 inches outside diameter, and 6 feet 6 inches extreme length, with flat ends. The front end is the front tube-plate for the tubes, and the uptake is of sheet-iron made separately, and bolted to the front of the shell.

There is one furnace, and it is contained in a cylinder of 2 feet inner diameter, and 4 feet 11¼ inches extreme length. In this cylinder are the grate-bars and the bridge-wall. The grate-bars are 4 feet 3 inches long, and the average breadth of the grate-surface is 1·96 feet.

The top of the grate-bars, at the front of the furnace, is one foot below the furnace crown; and, at the back of the furnace, 1 foot 4 inches below this crown; the breadth of each grate-bar is 9-16 inch, and the width of the air-spaces between them is ⅝ inch. The least water-space between the furnace and the shell is at the bottom of the latter, and is 3 inches wide, including thicknesses of metal.

The opening for the furnace-door is a semicircle of 20 inches radius. The door is of wrought iron, hinged at the bottom and latched at the top. It has a perforated lining-plate for the distribution of air, and two registers for the admission of air above the incandescent fuel. The aggregate air-opening in the two registers is 13·5 square inches.

The bridge-wall is an iron casting faced with brick. Its top is 6 inches above the top of the grate-bars, and its width is 5 inches. The height from the crown of the furnace to the top of the bridge-wall is 10 inches.

The back smoke-connection has a flat top, a flat back, and a flat front. The sides and bottom are concentric with the boiler-shell, from which they are separated by a water-space 3 inches wide, including thicknesses of metal. The flat water-space between the back of the connection and the end of the shell is 3 inches wide, including thicknesses of metal. The extreme height of the connection in the clear is 29½ inches. The front of the connection is the back tube-plate of the tubes.

The tubes are returned along each side of the furnace, the top of the upper row being 3½ inches above the furnace-crown. The tubes are of iron, lap-welded. Six of them are 2¼ inches in outside diameter, and the remaining fifty-four are 2 inches in outside diameter. Their metal is 1-10 of an inch in thickness. The tubes of each row, horizontally, are placed opposite the spaces between the tubes of the

row, above and below. The least water-space between the tubes is $\frac{5}{8}$ of an inch in the clear. The tube-plates are of $\frac{1}{2}$ inch thick metal, and the length of the tubes in the clear of the plates is 4 feet $10\frac{3}{4}$ inches.

The uptake is a construction of sheet-iron separate from the boiler-shell, and bolted to it. The outer periphery is concentric with the boiler-shell, and the inner periphery is concentric with the furnace. The front projects over the fire room $4\frac{3}{8}$ inches at the bottom and 13 inches at the top. On this inclined surface are two uptake-doors opposite the tubes. They are hinged at the top and latched at the bottom, and are of sufficient area to embrace all the tubes. From the top of the uptake, (at the level of the top of the boiler shell) which is rectangular in horizontal section, the chimney is drawn in to a circle of $10\frac{1}{2}$ inches inner diameter at the height of 20 inches above the top of the shell. At this height the upper cylindrical part, 4 feet 6 inches high, is hinged on. The chimney, for the whole height above the top of the shell, is surrounded by an air-jacket of $14\frac{1}{2}$ inches outside diameter, perforated with a row of holes at top and bottom.

Immediately over the boiler-shell, and connected to it by a pipe of 8 inches diameter, is a boiler-plate cylinder with flat ends serving for steam-room additional to what the upper part of the shell contains. The inner diameter of this cylinder is 15 inches, and its inner length is 4 feet $11\frac{1}{4}$ inches. It is of $\frac{3}{8}$ inch thick iron, and its upper part contains a dry-pipe, of 3 inches diameter, extending its whole length and perforated along the upper side. The steam-pipe to the engines is an extension of this dry-pipe. The hole in the top of the boiler-shell within the 8 inches diameter pipe is 4 inches diameter, and through it the steam passes to the cylindrical steam-room from the shell. The space between the top of the boiler-shell and the bottom of the cylinder is $3\frac{3}{4}$ inches.

The cylindrical portion of the shell is of $\frac{3}{8}$ inch thick iron. Its flat ends, and the flat back of the smoke-connection, are of $\frac{1}{2}$ inch thick plate. All seams are double riveted.

In the front of the shell, opening into the uptake, is an elliptical man-hole with diameters of 11 and 14 inches. And in the lower portion of this front, beneath the uptake, are two elliptical hand-holes, with diameters of $2\frac{1}{2}$ and 5 inches.

The entire exterior of the boiler-shell is felted, lagged, and covered with sheet-iron.

(To be continued.)

Chemistry, Physics, Technology, Etc.

NEW PROCESSES IN PROXIMATE GAS-ANALYSIS.

By Professor Henry Wurtz, of New York.

[*Communicated in part, with Experimental Illustrations, to the American Gas-Light Association, October* 22, 1874.]

(Continued from Volume lxix, page 226.)

If, however, the gas be strongly sulphuretted, this plan will not do, as sufficient *sulphuric anhydride* is then set free to act appreciably on the hydrocarbons present, both by absorbing them and by engendering sulphurous acid.

After the whole train is put in action, during the actual analysis, should it be practicable to *watch* the apparatus during this stage, A may be kept immersed in the hot water in B, which will save subsequent expenditure of time in preparation for the final weighing. K must be watched from the first, and if it turns brown very rapidly—indicating *much* oxygen present—the current must be stopped when the meter has shown about one foot flow, and K L taken out to be weighed: resuming—after recording the meter—with a direct connection from J to M. This, because it may not be safe to trust K for more than one foot of gas *largely* contaminated with air.

In the absence of an adequate number of arrows in this cut, it will, I trust, be clear on a little examination, that the course of the gas is from M to the inlet of the meter at its axis in the rear, and out again, through the rubber tube O, to the final CaCl-tube P, and thence through the vertical glass tube R, at the top of which it may be kindled.

The usual rate of flow advisable, if attainable, with this train, is about one foot per hour; and the whole amount of gas analyzed should not be ordinarily more than ten cubic feet. This does not necessarily apply to the NH^3 and H S determinations, however; as in a well-purified street-gas the amount of these in ten feet only might be

scarcely appreciable. Therefore, after some ten feet has passed the meter, the latter having been read and recorded, direct connection should be established from F to M, the intervening members being thrown out. The flow may then be kept on through A, E, F, M, the meter, and P, even up to 50 or 100 feet, or until the registered volume is judged sufficient for these two constituents.

In these latter cases it is obvious that the common one-dial photometer-meter, as figured, will not answer; and it will be necessary to provide a meter having dials enough to register continuously up to 100 feet, as well as down to decimals of a foot.

In this case, unlike the operation with the crude gas, no general distilling or transferring process is required before the final weighings. It is only essential that A should be free from condensed moisture at the close, by reason of immersion in B; or that it should be subsequently freed therefrom, by means of a dry gas-current through and from the preparatory train.

V.—Of the Dimensions of the Apparatus, etc.

The sizes and weights of the different pieces of apparatus must not be left unexplained.

Flask C is of one pint capacity. It is convenient to have at least four different sizes or patterns of U-tubes. The largest, represented by H in the preparatory train, is about 13 inches high, 1·1 inch internal calibre, and 2·25 inches between the limbs. The second size is the most useful size, the corresponding dimensions being about $8 \times \cdot 9 \times 2$ inches, and is exemplified in Fig. 1 by F, G, H, L, M and the omitted CaCl tube; and in Fig. 4 by G, H, K, and P. The third size, C and D in Fig 2, and F in Fig. 4, may be $6 \cdot 5 \times \cdot 6 \times 1 \cdot 9$; and the smallest, represented in duplicate in A, and by J and L in Fig. 4, also by J and M in Fig. 1, is about $4 \times \cdot 4 \times \cdot 75$.

The relative proportion of the different members of a train to each other is worthy of careful consideration in planning an investigation, and much time and labor may often be thus saved. These proportions will differ with the conditions and with the nature of the gas very largely.

For convenience in weighing, wires may be attached, as has been shown in the cuts in one case only—the CaCl-tube in GF in Fig. 2. As before stated, these wires, unless of platinum, are objectionable in the atmosphere of a gas works, and the tubes can just as well

be simply laid across the pan of the balance. The balance should be capable of bearing safely a load of at least 300 grams or a little more, and indicating one milligram, that is, of turning perceptibly with the 300,000th of its load.

One of the worst obstacles to accuracy in weighing large glass apparatus delicately being the well-known attraction of glass for moisture, I have adopted, as hinted before, a very valuable device; simply to provide thin polished brass, or tin cases, closing tightly, but *not hermetically*, suited in size to different sizes of tubes, within which the latter are shut up while warm and dry.

VI.—Of the Calculation of the Results.

To obtain from the observed volume, as per meter, the true initial volume of the mixed gas and spray operated on, requires some calculation. Taking first the most complex case, that of a crude coal-gas from the hydraulic main, we shall have the following

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FACTORS.		DENSITIES.*
The observed volume, in cubic feet and decimals:	which call v.	
The final Fahr. temperature of the gas;	which call $t°$.	
The weight of liquid in grains;	which call Lt. . .	(Water = 1) = 1·25
The weight of liquid water, in grains;	which call Lw.	

*The densities adopted for NH^3, HS and CO^2 are the theoretical ones employed by Bunsen in his Gasometry. Other authorities differ perceptibly about all these. The density of aqueous vapor adopted, is very close to Regnault's figures. Bunsen used ·62205.

The weight of initial watery vapor;

			which call *wv*** . .	(Air = 1)	= 0·6220
"	"	"	gaseous ammonia (NH^3) which call *am.* . . .	" "	= 0·5896
"	"	"	gaseous sulphuretted hydrogen; which call *s.*	" "	= 1·1749
"	"	"	gaseous carbonic acid; which call *c.* . . .	" "	= 1·5202
"	"	"	naphthaline vapor; which call *n.* . . .	" "	= 4·5700

Other constants required in our calculations are:

1. The coefficient of dilatation of coal gas for the Fahrenheit degree. I adopt

$$\frac{1}{491\cdot9}$$

2. The number of grains of pure water in a cubic foot at 60° Fahr., which I make 436320.

3. The number of grains of dry air in a cubic foot, at 32° Fahr. equal 565, according to Regnault.

As to the first, Ph. Jolly has recently given (*Chemisches Centralblatt*, 1874, p. 241; from Poggendorff's *Annalen*) new determinations, which for one Fahr. degree are:

For H gas, ...	·002031
For CO^2 gas, ...	·002059
For Air gas, ...	·002039†

As coal gas is almost half hydrogen, I have adopted ·002033, which equals $\frac{1}{491\cdot9}$.

** It must not be forgotten that an addendum to *wv* is derivable from the final weighing of the bisulphate of potash tube.

† The figure of Regnault for this constant for air is almost the same as this; that of Magnus is a trifle lower. For Fahr. degree:

Regnault ·0020389, or $\frac{1}{490\cdot46}$

Magnus ·0020377, or $\frac{1}{490\cdot75}$

For calculating the third constant, I have adopted as a basis a figure kindly calculated for me by Prof. A. M. Mayer,* directly from the original determination of Regnault, for a liter of dry air under normal tensions, equal 1·29278 gram. Cooke's Chemical Philosophy gives this figure equal 1·29319 gram.

From Mayer's figure I get, closely enough, for one cubic foot air, at 32° Fahr. 565 grains.

In the most complex case of all, as in Fig. 4, when a wet meter is used, and the gas measured with a certain content of aqueous vapor, afterwards determined by means of the CaCl tube P; we have, in this weight, still another factor, wv'.

The following crude expression may now be first jotted down: V being the corrected initial volume† sought, in cubic feet, at 60° Fahrenheit:

$$\text{(A.)}\qquad V = v + \frac{60 - t^\circ}{491\cdot9}v + \frac{Lt}{436320 \times \text{dens. } Lt} + \frac{Lw}{436320} + \frac{wv}{565 - \frac{(60 - t^\circ)\,565\,\text{dens. } wv}{491\cdot9}} - \frac{wv'}{565 - \frac{(60 - t^\circ)\,565\,\text{dens. } wv'}{491\cdot9}} + \frac{1}{\frac{(491\cdot9 - 60 + t^\circ)\,565}{491\cdot9}}\left(\frac{am}{\text{dens. } am} + \frac{s}{\text{dens. } s} + \frac{c}{\text{dens. } c} + \frac{n}{\text{dens. } n}\right);$$

which, on interpolating the density figures above, may be reduced to

$$\text{(B.)}\qquad V = 1\cdot12198v - \cdot002033t^\circ v + \cdot000002292\left(\frac{Lt}{1\cdot25} + Lw\right) + \frac{wv - wv'}{522\cdot134 + \cdot71443t^\circ} + 491\cdot9\left[\frac{am}{143876\cdot256 + 333\cdot124t^\circ} + \frac{s}{286703\cdot2 + 663\cdot82t^\circ} + \frac{c}{370964\cdot525 + 858\cdot9t^\circ} + \frac{n}{1115187\cdot4 + 2582\cdot05t^\circ}\right].$$

---

* Prof. Mayer remarks that he found a slight error in Regnault's own reduction of his observations.

† It should here be explained, that by "initial volume" is not meant the volume of the gas *in the main;* where, of course, by reason of the higher temperature, the aqueous spray Lw, and even part of Lt, may not exist; but strictly the volume and state of aggregation assumed by the gaseous mixture, as it passes the initial members E and F of the train in Fig. 1.

In the case in which $t°$ equals 28° Fahr., as when the final temperature is reduced quite down to that of melting ice, we may express it thus:

$$(C.) \qquad V = 1{\cdot}065065v + {\cdot}000002292\left(\frac{Lt}{1{\cdot}25} + Lw\right) + \frac{wv - wv'}{542{\cdot}14}$$

$$+ \frac{am}{311{\cdot}45} + \frac{s}{620{\cdot}65} + \frac{c}{803{\cdot}06} + \frac{n}{2414{\cdot}1}.$$

In the case of purified illuminating gas, as from street mains, in which the suspended tar and spray should be, and ordinarily are inappreciable, the second right hand member of the equation (C) disappears, as also the last factor representing the condensable naphthaline; and if, in addition, the gas has been measured dry, by means of a dry meter at the tail of the train, so as to eliminate wv', and also at 32° Fahr., we have (omitting also an inappreciable fraction in the first factor) the simplest case of all;

$$(D.) \qquad V = 1{\cdot}0651v + \frac{wv}{542{\cdot}14} + \frac{am}{311{\cdot}45} + \frac{s}{620{\cdot}65} + \frac{c}{803{\cdot}06}.$$

The correction for *Atmospheric Pressure* has not been introduced into the above, and is independent thereof. In exact work, the barometer must of course be observed at short regular intervals, and V should be further corrected by reduction to the standard pressure of 30 inches or 762 mm. This is simple. Calling the volume as thus corrected V; and the mean of the barometric observations P. Then—

$$V : V :: 30 \text{ inches} : P;$$

the volumes being inversely as the pressures; and—

$$V = \frac{P}{30}V;$$

whence a rule easily remembered. Multiply the whole of the right hand sides of the above equations by

$$({\cdot}03333+)P.$$

Equation (D) may then—corrected further for atmospheric pressure P—become:

$$(E) \qquad V = \cdot 0355 P v + \cdot 033333 P \left[\frac{wv}{542 \cdot 14} + \frac{am}{311 \cdot 45} + \frac{s}{620 \cdot 65} + \frac{c}{803 \cdot 06} \right].$$

To the above discussion, it seems proper to append the remark, that the data determined by it, while necessary to the gas-chemist, are not indispensably needed by the mere practical expert; who may be more concerned to refer the proportions of the constituents, as found, merely to the volume of *purified* gas, brought to, or near to, normal conditions of tension and moisture. This is a simpler affair. For the bottle of broken ice in the above train, Fig. 4, I substitute, in this case, a similar one filled with *clippings of clean sponge saturated with water*, to serve the double purpose of bringing the gaseous current both to the temperature of the air, and to the maximum content of aqueous vapor correspondent thereto. If this be accurately enough accomplished, the direct reading of the meter, whether the latter be wet or dry, will be the required volume; subject only to the barometric correction above specified. The final CaCl-tube is then not needed, though it might still be used as a check upon the process, and will give a general and *precise* datum from which the gas may be calculated to any standard of temperature and moistness.

VII. Examples of Analytical Results Obtained by one of these Methods.

To illustrate the work turned out by the Analytical Train in Fig. 1, operated as specified above, I shall cite some of the figures obtained by me in the course of an investigation made some months since upon an apparatus now in use at the Works of the Harlem Gas-Light Co., in New York; which covers a novel principle of action, consisting in forcing crude coal gas—before cooling to atmospheric temperature, and in a finely divided state—through the liquid products of the retorts, and of the incipient condensation of the gas itself, constituting a species of straining or filtering of the crude gas through a liquid medium.

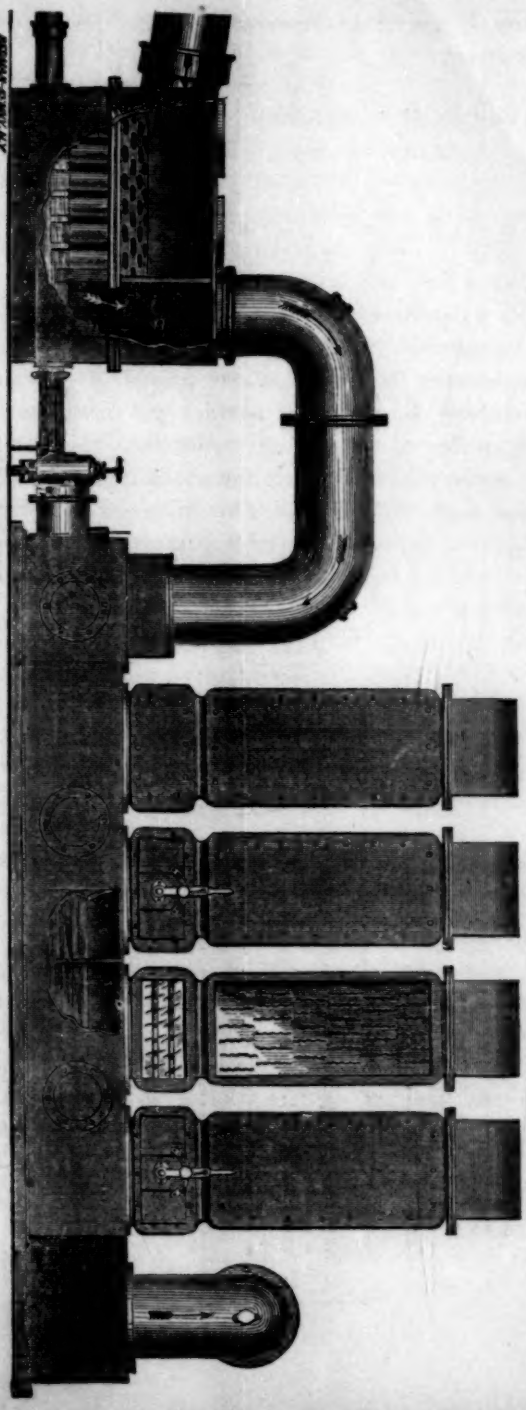

Fig. 5. "The St. John and Rockwell Scrubbers."

Weights: Grains per 100 cubic feet.	Crude Gas from Hydraulic Main.	Condensed Gas from Inlet to Purifiers.	Grains taken out of each 100 feet, by Scrubbers.	Percentage taken out of each Impurity.
1. Water	3515·2	2674·5	840·7	23·92
2. Tar	515·0	44·0	471·0	91·46
3. Smoke, soot, dust, etc	265·9*	55·7	210·2	79·05
4. Naphthaline (condensable)	123·5	25·0	98·5	79·77
5. Ammonia (NH^3)	339·4	237·0	102·4	30·18
6. Sulphuretted hydrogen	1234·9	1105·1	129·8	10·51
7. Carbonic Acid	1698·0	1522·1	176·0	10·36
Totals	7691·9	5663·2	2028·7	26·39
Totals, without the water	4176·7	2988·8	1188·0	26·05
Average Temperatures, Fahrenheit	107°·5	94°·6		
Volumes: Cubic feet per hundred.				
Sulphuretted Hydrogen	1·93	1·73	0·20	10·88
Carbonic Acid	2·07	1·86	0·22	10·62

NOTE.—Dividing the above weights by 70, gives closely enough, the lbs. *per ton* of the Impurities.

* With some Naphthaline, as has been explained above.

In the cut, Fig. 5, is represented on the left, one of the "boxes" of St. John. The gas from the hydraulic main is pumped down through the vertical tubes and is obliged to rise through the perforated horizontal diaphragms immersed in the liquids that collect in the box, or arrive therein from the hydraulic main through the lower pipe.

The apparatus on the right is a form of "dry scrubber," appended to the "boxes." The number of boxes employed is two or more—at the Harlem Works two—this depending on the volume of gas to be dealt with. During my analyses some 20,000 cubic feet per hour passed the apparatus. Two trains after the plan of Fig. 1 were attached, one just before the extreme left-hand arrow, and the other near the extreme right-hand arrow. The results obtained were as seen in table; about seven feet of gas in all having traversed each train during the analyses:

The coal used was a highly sulphurous, but rich variety, from West Virginia, known as the "Murphy Run Coal." The temperatures during the operation were as follows:

Gas in the Hydraulic Main, ...	125° Fahr.
Gas entering first, or left-hand Train, . . .	108° "
Gas entering second, or right-hand Train, . .	95° "
Refrigeration while passing Condenser, . .	13° "

APPENDIX.—Note from Prof. Wurtz.

Mr. Editor:—On looking over the installment of my paper on "Proximate Gas Analysis," presented by you in your last issue, I have observed one passage involving error in the specification of my methods, to which I beg your permission to direct the attention of your readers: page 226; lines 10, 11 and 12 from top; from "K being" inclusive, on to the end of the paragraph substitute as follows:

"L replaced, KL weighed—after applying stoppers like DD in Fig. 1, to prevent ingress of aerial oxygen—and the whole put in position, as attached to J."

Also, after the last word "temperatures," at the bottom of this same page, it may be well to supply the following note, in parenthesis:

(See *ante*, Graham's experiment; page 218 under *Sulphuretted Hydrogen*.) Respectfully, H. W.

ON THE CAUSE OF THE LIGHT OF FLAMES.

By W. Stein.*

The correctness of the old and well-founded conception that the light of flame is caused by incandescent carbon molecules, has been disputed by Dr. Frankland, who contends and tries to prove that it is derived from hydrocarbon vapors. It is evident that the old theory would have to give place to the new doctrine as soon as the untenability of the former and the correctness of the latter are proved. But neither the one nor the other has, I think, yet been done. Professor Frankland can, therefore, only be pleased if the present paper subjects the *pros* and *contras* of the new and old theory to an impartial examination.

I must mention that I have not been able to read the original paper of Dr. Frankland, and have only had the opportunity of consulting "Dingler's Journal," the "Chemical Centralblatt," the "Annual Report of Chemistry," and the "Ann. Chim. Phys." According to these, Frankland considers that the light of the flame is derived from very dense hydrocarbon vapors, of which he particularly mentions benzine and naphthaline.

As proof of his ideas he mentions: That the soot deposited on a cool surface, when introduced into a flame, does not consist of pure carbon, but that it contains also hydrogen; that, in fact, it seems nothing else than a collection of the densest light giving hydrocarbons, whose vapors condense on the cold surface.

Against this we may mention that not only do the heavy hydrocarbons, but even marsh gas, split up at high temperatures on exclusion of atmospheric air; and as the hydrocarbons, whose vapors are supposed to cause the luminosity of the flame, are precisely under such conditions before they come in contact with the air, it cannot be doubted that they suffer decomposition into carbon and hydrogen in the luminous portion of the flame. It is of little importance whether the eliminated carbon is chemically pure, or whether it contains still a hydrogen compound; the important question is this, Is the soot held by the flame in the shape of vapor or in the solid form? If the soot was nothing but a conglomeration of the densest light-giving hydrocarbons, whose vapors condense on a cool body, then, when sufficiently highly heated by exclusion of air, it ought to reassume

[* Translated from the *Journal für Gasbeleuchtung* for the *London Journal of Gas Lighting*, and reprinted from the latter Journal.—Ed.]

vapor form. This is, however, not the case, as every one will find who tries the experiment.

Its chemical composition is just as little favorable to Frankland's view. It ought, presumedly, to vary according to the lighting material from which it was derived—nay, even according to the place of the flame wherefrom it was deposited. It is well known that the temperature of the flame varies in various places, and Magnus' experiments have proved that from heavy hydrocarbons at a less high temperature a hydrogenous tarry product besides hydrocarbon is also eliminated. The soot whose analysis I give was obtained from a bat's-wing burner by allowing a small silver basin, filled with water, to dip for about two or three minutes into the flame. Benzine removed traces of a solid yellow body, but the small amount of it prevented it being further investigated. Alcohol, and alcoholic solution of caustic potash, and dilute sulphuric acid, dissolved nothing.

After being carefully and repeatedly washed with boiling water and dried at 130°, 0·206 yielded: Carbonic acid 0·6985, water 0 0195, ash 0 0020, which amounts in 100 parts to:

	Containing Ash.	Free from Ash.
Carbon,	96·446	97 390
Hydrogen,	1·051	1·061
Ash,	0 970	——
Oxygen,	1·533	1·549

I attribute the presence of oxygen to a small amount of water, which, even at 130°, was still retained, and this when deducted gives the composition of 100 parts of soot free from water and ash as consisting of

Carbon,	99·095
Hydrogen,	0·905

This analysis is in accordance with the chemical composition of the soot of the flame, and with the well-known behavior of heated hydrocarbons.

2. "How could the light of a flame be as transparent as in reality it is, if it was filled with solid carbon particles?" asks Dr. Frankland.

In reply to this, it must be admitted that one is able to read the writing held behind the flame of a bat's-wing burner. It is, however, easily observable that the flame is more transparent in the lower, non-luminous portion. The reading becomes also more difficult through a flame of greater thickness, and impossible through the flame of a

candle or petroleum burner. If, as is proved hereby, the transparency of a flame is only very limited, it may be remembered that one can also read the same writing through media which are known to be filled with solid particles; for example, through a piece of opal glass, oiled paper, or linen. The partial transparence of the flame cannot, therefore, serve as a proof of the absence of carbon molecules.

3. To understand the further query of Frankland, "How could it be indifferent for photometrical measurement, whether the flame presents the flat or narrow side, if the light is given by solid carbon molecules?" we have to recollect an observation of Arago. At Paris they wanted to know what position the flame of the street-lamps had to be in to produce the best light for the *trottoirs* as well as for the carriage road. Arago made experiments, and found that the narrow side of the flame radiated as much light as the broad or flat side. This result caused general surprise, because it was assumed that light was only given off from the surface of a flame, the surface layers of carbon particles absorbing or retaining the light of the interior layers. It may, however, easily be understood that such a view arises only from a misapprehension of the process. A body can only lessen or stop the light which falls upon it from another body, if it is either only very little or not at all luminous. If both bodies possess equal luminous power, the result will be double in effect. Two carbon molecules placed one behind the other, and both radiating the same amount of light, cannot possibly weaken each other; their radiations, on the contrary, must be considered as two waves of equal amplitude and velocity, traveling either one immediately after the other, or combining in such a way as to double the height and depth. The luminous power of a flame must therefore be just as large on the narrow as on the flat side, because in both positions the number of the light-radiating carbon molecules is equal. The light appears, however, to the eye to be denser on the narrow side, because it is produced by a greater number of molecules vibrating, and after or behind one another.

4. To demonstrate that his view of the luminosity of vapors is not without example, Frankland refers lastly "to the development of light which is produced by the burning of arsenic, phosphorus, and bisulphide of carbon in oxygen, at ordinary pressure, and by the burning of hydrogen and carbonic oxide at higher pressures, in which cases the assistance of solid particles cannot be presumed."

Scientifically valuable and interesting as all this is, it does not demonstrate that the process of our luminous flame is an analogous one. Moreover, the fact that solid bodies are by preference apt to become light-radiating is not at all changed by this, and thus far it is demonstrated only that there can be but one solid body to which the luminosity of flame can be attributed. If we consider, therefore, all the before mentioned facts, we can draw only one conclusion—namely, "That the light of our illuminating flame comes from incandescent carbon molecules, and that the old view is still to be retained."

Experience teaches that for the artificial production of light, a high temperature is requisite before all things. Temperature is, however, that part of the total heat of a body which influences the surrounding parts, or the surplus of atomic movement which is not consumed by its inner work. A high temperature means, therefore, a great excess of such movement, which again is identical with a greater number of momentary vibrations. In fact, the movement of light and the movement of heat differ essentially by regularity (*Rhythmen*) and greater velocity. The movement of heat passes, therefore, presumedly into movement of light, if it has reached the lowest number of vibrations for light—namely, those of red light. If, after a greater and greater rising of temperature up to its highest possible degree, the rapidity of movement increases more and more, we observe, besides the red light, first, yellow light, forming orange with the former; later, we meet also blue light, which, however, in most cases, only serves to form white light with the red and yellow, and which is only predominant in very rare cases, as observed by Deville. Under ordinary circumstances, we only get a yellow or red light containing more or less white. The more white it contains the greater is, naturally, its effect of light; and, as white only appears at the highest temperatures, it becomes evident that the temperature of a flame does not exert a secondary influence on its luminosity, but is its principal factor. The second factor is the eliminated carbon, the molecules of which radiate the light. The luminosity of two flames of the same temperature corresponds, therefore, to the number of its carbon molecules, and "luminosity in general equal to the product of the radiating molecules and their temperatures" for illuminating purposes, it may be presumed that the latter should amount to at least 1000°.

The above-mentioned phenomena of light may easily be observed on solid bodies if heated. They are not observable on gases as long

as they expand unhindered. It would, however, be wrong to attribute this negative behavior to the circumstance alone that, by the unhindered expansion, the amount of the added, or produced heat was changed into power. This is contradicted by the high temperature which, amongst others, the non-luminous explosive gas-flame *Knall gas*) possesses.

Besides, it is also observed that platinum wire becomes incandescent in every possible non-luminous flame, even in a flame produced by nitrogen on coal gas, if the requisite temperature to change heat into light is present.

If we may conclude from this that the atoms of gases may be brought into light vibrations without becoming luminous, then we possess bodies which conduct the light (the gases), and others which radiate the light (the solid bodies), analogous, as we have conductors of electricity and idioelectrical bodies.

An explanation of this difference is offered when light is considered as atomic movement. Its effect to the eye is then the product of quantity and velocity.

In a given space we find a much larger number of vibrating atoms if filled with solid matter than if filled with gas. The waves of light of solid bodies must, therefore, be much denser than those of gases, and exert also a more intense effect on the nerves of our eyes. "Light-conductors" differ, therefore, from "light-radiators" by the lesser density of their waves of light; for which reason they cannot, under ordinary circumstances, form "optical molecules," as I expressed it at another occasion. How powerfully the condensation of the waves of light affects the eye is shown by the effect of collecting lenses.

The minimum of density which a body must possess to become light-radiating—that is, to become self-luminous to the eye, or to appear a source of light—is just now not known; but one sees, if this view is correct, the possibility of even vapors or dense gases becoming luminous, as Frankland tried to prove. The results of his experiments might even serve as foundation for the lowest limit of density, if it were not so very difficult, nay, even just now impossible, to make such an experiment in a manner as to exclude every doubt about the assisting influence of solid bodies.

SAFETY-VALVES.*

(Report of a Committee of the Institution of Engineers and Shipbuilders of Scotland.)

At the first general meeting of the present session of the Institution of Engineers and Shipbuilders in Scotland, a report on safety-valves was presented by a committee appointed to deal with this question. The report consists of (1) experiments made upon the outflow of steam through orifices; (2) experiments made "to ascertain the pressure to which steam will rise in a boiler above the load pressure when the valves are of the same size, having an area of half-an-inch per foot of grate surface, but at different pressures, the whole of the steam raised being allowed to pass away by the safety-valves when unassisted;" (3) experiments made "regarding the strength and action of springs as applied to the loading of safety-valves;" (4) conclusions arrived at by the committee as to the form, manner of loading, and dimensions of safety-valves. The first part of the report contains the account of an exhaustive series of experiments, made by Mr. James Brownlee, to determine the outflow of steam at different pressures through orifices of various forms, and commences with a recapitulation of the views held on this question by various scientific observers. In this part of the report it is pointed out that "until within the last twenty or thirty years the flow of weight and velocity with which steam and other elastic gases issue through an orifice was computed by the same rule which applies to water or other inelastic liquids." Weisbach, however, showed that this was incorrect, and believed that "the *quantity* of steam which flows through an orifice from a boiler under a pressure of two atmospheres is much greater when that orifice opens into the atmosphere than when the same orifice communicates with the condenser of a steam-engine." According to Mr. R. D. Napier's view, "the flow is neither increased nor diminished by reducing the outside pressure to less than half the inside pressure." Professor Rankine's view was that "the flow is neither increased nor diminished by reducing the outside pressure below about 58 per cent. of the absolute pressure in the boiler."

In conformity with this view a table is given in the report, showing, amongst others, the weight of steam in pounds discharged per minute

[* Reprinted from *Iron*.—Ed.]

through the best form of orifice, one square inch in area, and at absolute pressures varying from 25·37 lbs. to 100 lbs., the weight at these pressures being respectively 22·81 and 86·34 lbs. A table is given of the reaction of steam from experiments made by Mr. George Wilson.

Mr. Brownlee, to satisfy himself on this subject, made a series of nearly daily experiments, extending over a period of about six months. The method adopted was to allow steam, drawn from six boilers, to pass through a 1¼-inch valve into a chamber where the pressure could be kept steady. From this chamber the steam passed through a carefully-measured orifice into a second chamber, where the pressure could also be regulated. The steam finally entered a "worm" placed in a tub containing a circulating supply of cold water. The steam was thus delivered condensed, and at a temperature from 70 to 100°. The water thus obtained was measured and weighed, and the time observed. By this arrangement a flow of steam from a higher into a lower pressure was obtained. Examples of this are given in the report, from which it appears that it is doubtful whether the outflow of steam at 80 lbs. is affected by increasing the outside pressure from 17 to 48 lbs. It was found that the flow of weight through a square-shaped orifice was from 11 to 13 per cent. less than through an orifice with a rounded entrance. A third chamber was added to the apparatus, from which it appears that when the absolute pressure was maintained steady at 100 lbs. in the first chamber, the pressures obtained in the second and third chambers were 81 lbs. and 18 lbs. respectively, "showing that the steam which flows from 100 lbs. into 81 lbs. is the same in quantity as passes from 81 lbs. into 18 lbs., the two orifices being of the exact same size and form."

From the results obtained from these experiments the proper size of safety-valve openings was determined, from which it appears that "the weight in pounds of steam discharged per minute per square inch of opening, with square-edged entrance, corresponds very nearly with three-fourths of the absolute pressure in the boiler, as long as that pressure is not less than 25·37 lbs.," and that "the area of opening, requisite to the discharge of any given constant weight of steam is very nearly in the inverse ratio of the pressure." By allowing an evaporation of 3 lbs. of water per minute per square foot of

grate, the following rule for area of orifice of valve is obtained:—

$a = \frac{4 \times \text{square feet of grate}}{p_1}$ where a = area of orifice in square inches, and p_1 = the absolute pressure.

The second part of the report contains the result of a series of experiments made by Mr. D. Rowan, to ascertain the increase of pressure in the boiler over the load on safety-valve. These results are tabulated, and the increase of pressure stated as a percentage, which ranged from 160 with a load of 5 lbs., to 15·5 with a load of 45 lbs. The boiler was tubular, having 25 square feet of grate surface, and 746 feet heating surface; two valves were used of $2\frac{7}{8}$ inches diameter. This part of the report closes by showing that this increase of pressure is principally caused by the use of valves of too small dimensions.

The third part of the report treats of "Loading safety-valves by direct springs," and contains rules for the proportioning of springs from experiments made by Mr. Walter Brock. The "lift" having been fixed, a percentage of the load remains to be decided upon, "which is not to be exceeded by the additional load due to the compression or extension of the spring caused by the lift of the valve," this is assumed as $2\frac{1}{2}$ per cent. of the original load; from this it follows that "the compression or extension to produce the initial load, shall be forty times the lift of the valve." The following formula is given for the compression or extension of one coil of the spring:—

$E = \frac{d^3 \times w}{D^4 \times D}$. Where E = Compression or extension of one coil in inches, d = diameter from center to center of steel composing spring in inches, w = weight applied in pounds. D = diameter or side of square of steel, of which the spring is made, in 16ths of an inch. C, a constant, from which experiments may be taken as twenty-two for round steel, and thirty for square steel. The total compression or extension is obtained by multiplying by the effective number of coils, which is taken as two less than the apparent number. Examples of the application of these rules to the loading of valves are given at close of this part of report.

The report concludes by an expression of opinion of the committee, from which we make the following extracts: "The present practice in this country of constructing safety-valves, of uniform size for all pressures is incorrect. The valves should be flat-faced, and the

breadth of the face need not exceed one-twelfth of an inch. The present system of loading valves on marine boilers by direct weight is faulty, and ill adapted for sea-going vessels. That two safety-valves be fitted to each marine boiler, one of which should be an easing valve. The dimensions of each of these valves, if of the ordinary construction, should be calculated by the following rule:—

$$A = \frac{18 \times G}{P}, \text{ or } A = \frac{0{\cdot}6 \times HS}{P}. \quad \text{Where}$$

A = area of valve in square inches.
G = grate surface in square feet.
HS = heating surface in square feet.
P = absolute pressure in lbs. per square inch.

"The committee suggest that only one of the valves may be of the ordinary kind, and proportioned as above, and that it should be the easing valve. The other may be so constructed as to lift one quarter of its diameter without increase of pressure. Valves of this kind are now in use, and one such valve, if calculated by the following rule, would be of itself sufficient to relieve the boilers, $A = \frac{4 \times G}{P}$ + area of guide valve or $A = \frac{\cdot 133 \times HS}{P}$ + area of guides of valve. If the heating surface exceeds 30 feet per foot of grate surface, the size of safety-valve is to be determined by the heating surface. Springs should be adopted for loading safety-valves, and should be direct-acting where practicable."

Automatic Writing Machine.—M. Th. Huppinger, says the *Revue Industrielle*, has just invented a machine for writing spoken words. The mechanism is not large, being about the size of the hand. It is so put in communication with the vocal organs, either the lips, the tongue, the larynx, etc., that their movements are transmitted through a series of articulated levers, and recorded upon a band of paper unrolled for the purpose. The writing consists of dots and dashes. As the instrument reproduces only the movement of the vocal organs, it is not necessary, in using it to speak loud. It may consequently be used for stenographic purposes, the person to whom it is attached simply repeating the words of the speaker after him, but inaudibly.

AWARD

OF

Scott Legacy Medals and Premiums.

HALL OF THE FRANKLIN INSTITUTE,

Philadelphia, April, 1875.

Notice is hereby given that the Board of Managers of the **FRANKLIN INSTITUTE** of the State of Pennsylvania, for the promotion of the Mechanic Arts, have in accordance with the recommendation of the COMMITTEE ON SCIENCE AND THE ARTS,

Awarded the Scott Legacy Medal and Premium

To JOHN G. BAKER, of Philadelphia, for Baker's Rotary Pressure Blower;

To HUTCHINS & MABBITT, of Philadelphia, for their Tilting Chair;

And to J. MARTON POOLE & CO., of Wilmington, Del., for their Improvements in Grinding Callender Rollers.

And said Medals and premiums will be delivered to them respectively, unless within three months from this date, satisfactory evidence of the want of originality in said inventions is lodged with the undersigned.

D. SHEPHERD HOLMAN,

April 3t. *Actuary.*